# STUDY OF BABCOCK TEST FOR BUTTERFAT IN MILK

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## I. INTRODUCTION

The Babcock test for butterfat in milk is used to determine the value of millions of dollars worth of products. It is employed to a considerable and increasing extent as a basis of payment for milk to be used as such, as well as for condensing and cheese making. It is also used in determining the milk production of individual cows and hence is an important means of determining their value.

Some questions have been raised as to the accuracy of the present method of carrying out the test and also as to the influence of different factors on it. It is the opinion of some that reading to the extreme ends of the fat column, as advocated in reading the test for milk, gives results which are higher than the true amount of fat present in the sample. Recently the manipulation of the test and the glassware used have been standardized and the use of the 8 per cent bottle in place of the 10 per cent bottle recommended. In view of the importance of the test, experimental work was undertaken to determine the accuracy of the test as carried out at present, and to study the influence of some factors upon it.

In presenting the results of this kind of experimental work, the fact that there is an appreciable difference in the readings by different individuals who are following the same directions should be borne in mind. The data given, therefore, represent the results obtained by one set of individuals. Coöperative

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work under the direction of some representative dairy organization would be the final way to settle definitely any question as to the accuracy of the test.

## II. PREVIOUS WORK ON THE ACCURACY OF THE TEST

The principle of the Babcock test for milk was discovered by Babcock in 1890 and in his report (1) he compares it with the gravimetric method, in which the milk was dried on asbestos and extracted with ether. On thirty samples of milk, mostly from individual cows, the two methods compare very favorably. In the two years following, reports from several of the experiment stations in this country by Snyder (2), Farrington (3), Patterson (4) and others (5) showed equally good agreements between the Babcock and gravimetric methods, in most cases. These were followed by favorable reports by Schutt (6) in Canada, Heinrich (7), Zehenter (8), and Schrott-Fiechtl (9) in Europe and by Shiver (10) in this country. The average results obtained by the authors mentioned are given in table 1.

The results in table 1 are not wholly comparable to the results presented in this paper for two reasons. The Babcock tests were undoubtedly all run in 10 per cent bottles and probably not much attention was paid to the length of graduation while in this work most of the results were obtained in 8 per cent bottles, all of which had a graduation of 63.5 mm. or more. The gravimetric method differed somewhat from the Roese-Gottlieb method, which was used in the work, and several modifications of it were employed. None of the modifications are recognized today to be as accurate for milk as the Roese-Gottlieb method as indicated by their having been replaced by it in the official methods (11) of the Association of Official Agricultural Chemists.

More recently Webster and Gray (12) and Smith (13) have pointed out the effect of the width of the neck of the bottles, or in other words, the effect of the length of graduation, on the reading. The effect was determined by weighing pure butterfat into the necks of the bottles and comparing the theoretical and actual readings in bottles with necks of varying widths. The wider neck means a deeper meniscus and a consequent greater

TABLE 1

*Comparisons between the Babcock and gravimetric methods on whole milk*

| AUTHORITY | NUMBER OF COMPARISONS | AVERAGE OF ALL BABCOCK READINGS ABOVE AVERAGE OF ALL GRAVIMETRIC RESULTS | AVERAGE OF DIFFERENCES BETWEEN BABCOCK READINGS AND THE GRAVIMETRIC RESULTS* | ABSORBENT USED IN GRAVIMETRIC METHOD |
|---|---|---|---|---|
| Babcock (1)..... | 30 | 0.011 | ±0.089 | Asbestos |
| Snyder (2)..... | 43 | −0.026 | ±0.062 | Asbestos |
| Farrington (3)..... | 12§ | 0.050 | ±0.088 | Asbestos |
| Farrington (3)..... | 12§ | −0.075 | ±0.093 | Sand |
| Farrington (3)..... | 12§ | −0.129 | ±0.149 | Paper |
| Connecticut Experiment Station (5).. | 32 | Within 0.01 | 6 differ over ±0.10 | |
| Patterson (4)..... | 20 | −0.132 | ±0.153 | Paper |
| Schutt (6)..... | 32 | −0.088† | ±0.103§ | |
| Heinrich (7)..... | 27 | −0.03‡ | | |
| Zehenter (8)..... | 34 | 73.5 per cent Within 0.05 | 3 differ over ±0.10 | |
| Schrott-Fiechtl (9). | 100 | 0.001 | ±0.076 | Sand |
| Shiver (10)..... | 49 | 0.067 | ±0.095 | Paper |

* Differences between comparisons on individual samples. This shows the average of the differences above or below the gravimetric method as contrasted with the previous column which shows the balance of these differences. The differences above and below the gravimetric method might be large and yet their balance be zero thus showing too close an agreement between the two methods.

† From 12 of the comparisons.

‡ With 1500 revolutions, −0.22 with 800 revolutions. Diameter of wheel not given.

§ Same Babcock tests used.

excess reading. Some milk, but mostly cream bottles were used for their work.

Manchester (14) ran two series of comparisons between the Roese-Gottlieb method and the Babcock method using 10 per cent bottles of different lengths of graduation. His conclusions were that the results by the Babcock method were higher than results by the Roese-Gottlieb method except where bottles were used having a length of graduation of over 80 mm. for a 10 per cent bottle. For an 8 per cent bottle the minimum length of graduation was calculated to be 64 mm.

The Dairy Science Association (15) in their specifications and directions have recognized only the 8 per cent bottle and have specified a minimum length of 63.5 mm. (2½ inches) for the graduated portion of the neck.

## III. EFFECT OF DIFFERENT FACTORS ON THE APPEARANCE AND READING OF TESTS

Some preliminary work was done to determine the factors to be observed in order to obtain fat columns that were as free as possible from sediment, such as curd and charred materials, and to study the effect of some of these factors on the readings. It was not easy to constantly obtain tests on milk with practically clean fat columns. It seems to be in general more difficult for operators to obtain clean fat columns with milk than with cream.

Variations in the strength of acid, the amount of acid used, and in the temperature of the acid and milk would be expected to have an influence on the test but the control of these factors did not always produce tests that were equally satisfactory in appearance. Delay between the mixing of the milk and acid, and the whirling in the tester was also found to be an important factor. A smooth running tester is also essential in obtaining clean tests. Using the correct amount of acid of proper strength at the right temperature and allowing no delay between mixing and whirling always gave tests which were free enough from sediment in the fat column to be readily and accurately read, and in most cases they were practically clean.

### *Effect of strength of acid*

Experiments were run using different amounts of acids of 1.80, 1.81, 1.82, and 1.83 specific gravity having the temperature of the milk and acid at 70°F. All the tests with acid of 1.80 and 1.81 specific gravity had practically colorless fat columns and with the smaller amounts of acid, curd was present. With larger amounts of these acids where practically clean fat columns were obtained, the readings had a tendency to be 0.05 per cent to 0.10 per cent lower than with the proper amount of higher strength acids.

*Effect of amount of acid*

Experiments were run in which the variation in the amount of acid used was further studied. With acid of 1.83 specific gravity at a temperature of 70°F. the effect on the tests was studied when the amount of acid was varied from 10 to 20 cc. Under these experimental conditions which were carefully controlled quite satisfactory tests were obtained except with the

TABLE 2

*Effect on the reading of varying the amount of acid. Average results of four tests*

| | AMOUNT OF ACID OF 1.83 SPECIFIC GRAVITY | | | | |
|---|---|---|---|---|---|
| | 10 cc. | 12.5 cc. | 15. cc. | 17.5 cc. | 20 cc. |
| Series 1 | 4.25 | 4.29 | 4.30 | 4.30 | 4.29 |
| Series 2 | 4.28 | 4.34 | 4.34 | 4.35 | 4.30 |
| Series 3 | 4.51 | 4.56 | 4.65 | 4.59 | 4.64 |
| Series 4 | 4.53 | 4.60 | 4.61 | 4.63 | 4.62† |
| Series 5 | 4.70 | 4.79 | 4.78 | 4.82 | 4.81 |
| Series 6 | 4.49 | 4.49 | 4.53 | 4.51 | 4.55† |
| Series 7* | 3.91 | 3.98 | 3.96 | 3.99 | 4.01 |
| Average | 4.37 | 4.42 | 4.44 | 4.44 | 4.44 |
| Color‡ of fat columns | Yellow tint 2 | Yellow tint 2 | Yellow tint 1 | Yellow | Orange yellow |
| Amount sediment in fat columns | Some had appreciable amount white curd | Traces | Traces | Traces | Few had an appreciable amount of charred material |

* Five tests in this series.

† One reading omitted because of charred material.

‡ From color charts in Mulliken's Identification of Pure Organic Compounds, vol. I.

extreme amounts of acid there was a considerable tendency to sediment as indicated in table 2. The effect on the reading is also shown in the table. Three other series of five tests each are not included since the tests with 10 and 20 cc. could not be read in a majority of the cases due to curd or charred material. These

were run in a different tester which did not run smoothly. For 12.5, 15, and 17.5 cc. the average results obtained were 4.45, 4.48 and 4.47 per cent respectively.

One series of tests with acid of 1.82 specific gravity gave 4.20 per cent for 12.5 cc. acid and 4.28 to 4.30 per cent for other amounts of acid from 15 cc. to 22.5 cc.

It will be noted that with the smaller amounts of acid even where the fat columns were sufficiently free of sediment, the readings gave low results. These results and those given under Strength of Acid show that all fat columns that are practically colorless are apt to give low readings, even if nearly free from sediment.

With acid of 1.83 specific gravity, 15 cc. was considered to give the most satisfactory tests; this gives fat columns that are of a light yellow to a golden yellow color (the color indicated in table 2) which is a little lighter than that usually obtained. However, fat columns of this color give as high a reading as darker ones and the latter have more of a tendency to be accompanied by sediment.

*Effect of temperature of acid and milk*

Comparative tests with both acid and milk at 50°F., 70°F. and 90°F. with acid of 1.83 specific gravity showed that equally good appearing tests could be obtained if the proper amount of acid was used. Three to 4 cc. more of acid of 1.83 specific gravity at 50°F. and that much less at 90° were required to obtain the same kind of test as at 70°F.

Lower temperatures are preferable, however, for if there is any excessive preliminary mixing of the milk and acid before they are finally shaken together there is less tendency to produce unsatisfactory tests than at higher temperatures.

*Effect of delay between mixing and whirling*

A delay of any length between mixing the acid and milk and whirling in the tester always produced tests with more sediment in the fat column. This increase in sediment was noticed even if the tests stood only ten minutes. The failure to avoid this

delay caused considerable confusion in the first part of the work. An additional or an extra amount of mixing after the curd was dissolved seemed to have no advantage and only causes a delay.

This increase in sediment in the fat column is probably caused by an increase in the suspended material below the fat column. That more is present is shown by filtering the contents of the test bottles through Gooch crucibles, washing with water, alcohol, and ether and obtaining the amount of loss on ignition. On an average of ten comparisons 2.1 mgm. of suspended material, which was probably insoluble organic matter, were obtained when the tests were run immediately as compared with 3.6 mgm. when they stood thirty minutes. If more of this suspended material is formed there is more chance of it working up into the fat column.

Some suspended material is always present in Babcock tests although the amount and kind varies with conditions. This can be shown by filtering any test through a Gooch crucible and treating as above. With weak acids, etc., the sediment is undoubtedly casein which has separated out on dilution or cooling. Dilution of the acid-milk mixture to a certain extent causes a separation of casein, or probably a casein derivative. Beyond a certain dilution the casein remains in solution. This may explain the presence of some suspended matter in all tests and also why we still may obtain clean fat columns. The liquid next to the fat is dilute enough to keep the casein in solution, or else none of the casein solution has risen that high in the bottle, while further down we have the proper concentration for precipitation.

When charred material is present, this sediment is undoubtedly due to the sugar. This can be easily demonstrated for example by subjecting a 5 per cent milk sugar solution and a 3 per cent casein solution to the action of different amounts of acid under the same conditions as obtain in Babcock testing. The lactose solutions with the higher amounts of acid become black with considerable dark material in suspension. The casein solutions will all be clear except with very small amounts of acid. It will also be noted that the longer the sugar solutions

stand, the more action there seems to be on them, which probably explains the disadvantage of a delay between mixing and whirling.

In table 3 is given the amount of suspended material from solutions of some of the different constituents of milk subjected to the Babcock procedure with different amounts of acid. In most cases four bottles were filtered. It illustrates what has just been mentioned above. It will be noted that the casein is dissolved with more difficulty when fat is homogenized into the solution.

TABLE 3

*Insoluble organic material from Babcock tests on solutions of milk constituents*

| | AMOUNT OF ACID | | | | | |
|---|---|---|---|---|---|---|
| | 10 cc. | 12.5 cc. | 15 cc. | 17.5 cc. | 17.5 cc.* | 20 cc. |
| 1. 3 per cent casein solution | 1.5 | | | 0.5 | 0.6 | 0.6 |
| 2. Same with 3.5 per cent fat homogenized into it | 9.9 | 2.3 | 1.5 | 1.0 | 1.0 | 0.9 |
| 3. 5 per cent lactose solution | | | 0.7 | 2.6 | 7.7 | 6.6 |

*Delay of thirty minutes between mixing and whirling.

Since there is always some suspended material present in Babcock tests even when the above factors of strength of acid, etc., are controlled so as to keep it down to a minimum and thereby produce satisfactory tests, there is always a possibility of it working up into the fat columns in a few tests. This is probably why clean fat columns cannot always be obtained. There seems to be a very constant relation between the amount of sediment in a fat column and the height to which the lower black layer has become mixed up into the added water. The extent to which this lower layer rises is difficult to control and it would follow that the same would be true of the presence of sediment in some fat columns. The disadvantage of an unsteady tester is accordingly apparent.

The inability to avoid obtaining a few tests with some sediment present will probably also explain why it was difficult to come to any definite conclusion as to the relative advantages

between one and two fillings, shaking between whirlings and of other variations in the procedure. Two fillings, however, are advised as it seems to help in cases in which sediment is apt to get up into the fat column. The other variations did not seem to have any particular advantage.

*Effect of delay between adding acid and mixing*

Allowing tests to stand a reasonable time between adding the acid and the mixing it with the milk did not have the expected detrimental effect, providing the milk and acid are not mixed more than is necessary in work that is done at all carefully. The tests that stood the longest had slightly lighter fat columns. This is probably explained by the milk and acid gradually mixing, the casein being dissolved and some of the heat developed being lost so that when the milk and acid are finally mixed a lower temperature is obtained. Since milk and acid can stand in contact successfully for some time, it permits of adding acid to a number of bottles and shaking them together in a rack. This will also eliminate a delay between mixing and whirling if a large tester full is to be run.

*Effect of unheated tester*

The effect of testing in an unheated tester will depend on the temperature of the room, the length of time the tests are exposed to the room temperature after mixing, particularly in a cold room, and possibly on the type of tester. At ordinary room temperature (about 70°F.) tests will have the same reading whether run in a heated factory tester or a hand tester when run directly after mixing and the water added at above 180°F. Very little difference was noted between the results obtained in the heated turbine tester and the hand tester even when the room temperature was down to 50°F. as indicated in table 4.

A delay after mixing the acid and milk, thereby allowing the temperature to fall was detrimental as shown in the table. In another experiment at 70°F. the readings were lowered an average of 0.06 per cent for 8 tests that were allowed to stand as in

TABLE 4

*Effect of unheated tester*

| KIND OF TESTER | EXPERIMENT I | | | EXPERIMENT II | | |
|---|---|---|---|---|---|---|
| | Room temperature | Number of tests | Average reading | Room temperature | Number of tests | Average reading |
| Turbine tester | 70°F. | 6 | 5.03 | 70°F. | 12 | 4.58 |
| 8 bottle hand tester | 40–50°F. | 4 | 5.05 | 45–50°F. | 12 | 4.56 |
| 4 bottle hand tester | 40–50°F. | 8 | 5.02 | 45–50°F. | 8 | 4.55 |
| 8 bottle hand tester | | | | 45–50°F. | 6 | 4.48 |

Tests stood fifteen minutes between mixing and whirling.

experiment II. As delays are sometimes unavoidable it would be advisable in some way when testing in a cold room to heat the test and also place in a water bath before reading. It is apparently necessary to keep the contents of the bottles above a certain temperature to obtain correct readings.

### *Effect of speed of tester*

The speed of the tester cannot be cut down very much below the standard laid down by Babcock without lowering the reading as is shown in table 5. Increasing the time of whirling will help some but does not bring the reading up to normal in all cases. At normal speed two or three minutes variation in the length of time of running had no influence.

TABLE 5

*Influence of variations in speed of tester*

| | NUMBER OF TESTS | FULL SPEED | ¾ SPEED | ¾ SPEED × 2* | ½ SPEED | ½ SPEED |
|---|---|---|---|---|---|---|
| Turbine tester | 6 | 4.58 | 4.50 | 4.54 | 4.33 | 4.12 |
| Hand tester | 6 | 3.90 | 3.78 | 3.83 | 3.78 | 3.57 |

*Twice the usual time of running.

The importance of some of the factors mentioned above was probably recognized by Babcock but they have not been emphasized in recent directions for the test and hence not always observed in practice. Babcock (16) states that acid below 1.82

specific gravity may give a good test but cannot be depended upon. The effect on the reading, if the tests are good, is not stated. The nature of the sediment in the fat columns and some of the reasons for it are pointed out. In his first publication (17) he states that after mixing, the test bottles may be placed in the tester directly or allowed to stand several hours without harm. Probably recognizing the detrimental effect of a delay between mixing and whirling he states in his second publication (18) that the test bottles should be placed in the tester and whirled directly after the acid is added.

In general, to obtain the most satisfactory tests, the correct amount of acid of not less than 1.82 specific gravity, should be added preferably at 70°F. or below and after mixing the bottles whirled immediately in a smooth running tester (heated if room is cold), at the specified speed. The correct amount of acid is best determined by trial and it should give a fat column light yellow to golden yellow in color and which is practically free of sediment.

## IV. COMPARISON OF BABCOCK TEST WITH THE GRAVIMETRIC METHOD

### *Outline*

The principal object of this study was a comparison of the Babcock method with the gravimetric method for the determination of butterfat in milk. In order also to study the effect of breed and stage of lactation on the test, two consecutive samples were taken once a month during the lactation period from eight cows, two from four different breeds. Six determinations by the Babcock method (twelve determinations in the case of two cows) and duplicate determinations by the gravimetric method were made on each sample. The tests were made in 8 per cent bottles and any results that are given without mentioning the type of bottle are understood to have been made in them. In the case of two cows additional tests were made in 10 per cent bottles. Each series of tests was read by three members of the Dairy Department of Iowa State College. The readers are designated

by numbers. The only instruction given was to read to the ends of the fat column. It was thought that results by this group of individuals would be comparable with those of the average careful tester.

*Calibration of glassware*

The glassware used in the Babcock tests was calibrated according to the methods of the Association of Official Agricultural Chemists (19) except that in the case of the test bottles, the correct volume of mercury was measured from a narrow burette instead of being weighed. The burette was made from 3.5 mm. tubing by sealing on a glass stopcock. Repeated weighings of the mercury delivered checked the correct weight within 0.01 per cent reading on a Babcock bottle. The bottles were calibrated at the 4 per cent and 8 per cent divisions (5 per cent and 10 per cent divisions with 10 per cent bottles) to within 0.02 per cent as near as could be estimated. The length of graduations of the 8 per cent bottles were all over 63.5 mm. and those of the 10 per cent bottles over 70 mm.

The first set of bottles used was calibrated with water from the same burette as mentioned above, the burette being calibrated to deliver the correct amount of water. Later calibration with mercury showed that results are not the same as with water, the mercury tending to occupy slightly less space in the neck of the bottle; in other words, the same amount of fat, would tend to give a higher reading in bottles that were found to be correct when calibrated with mercury. The difference was found to average about 0.01 per cent for each 1 per cent reading and this correction was made in the results obtained with bottles calibrated with water.

It was found that two factors tended to make this difference between the two methods of calibration. An apparently perfect meniscus at the 8 per cent mark was not always easily attained with water in spite of the most careful cleaning with alkali and cleaning mixtures and when it was secured it was always found to be shallower than the meniscus at the 0 mark. This would

mean an error with the water calibration assuming that the mercury method is correct. The reason for the shallow meniscus is that the upper part of the neck, being more exposed to air currents, dries while waiting for the neck to drain and according to Osborne and Veazey (20) no method has been found for cleaning apparatus which will leave the apparatus free from contamination when it dries. The necks of the bottles were not wiped, but were allowed to drain, since wiping increased the tendency to form an imperfect meniscus and this also probably tended to increase the length of column of water used for calibrating.

*Gravimetric method*

The gravimetric method used was the one commonly known as the Roese-Gottlieb method. In this the casein in the milk is dissolved in ammonia, alcohol added and then the fat extracted by shaking successively with ethyl ether and petroleum ether in a special extraction flask. Since most of the previous work has been done with another method in which the milk was dried on some absorbent material and extracted with anhydrous ethyl ether, the Adams method in which the milk was dried on Schleicher and Schull fat free paper and extracted for four hours in a Sohxlet apparatus was also run on a number of samples. In a comparison of twenty-seven determinations in duplicate the Roese-Gottlieb was 0.042 per cent higher than the Adams method. These are the usual results and are probably accounted for by fat being held back in the dried casein in the case of the Adams method. The average of all the differences between the duplicate determinations by the Roese-Gottlieb method was 0.013 per cent.

*Procedure followed in making the Babcock test*

As a result of the preliminary study the following procedure was used in running the Babcock test for milk in comparison with the gravimetric method. The sample of milk was well mixed at 70°F. and a 17.6 cc. pipette full delivered into the Babcock test bottle. The correct amount of acid of proper strength (15 cc. of acid of 1.83 specific gravity in most of this

work) was added, both the acid and milk being at 70°F. After the acid had been added to the whole lot (twenty-four bottles) they were placed in a rack and the acid and milk thoroughly mixed. The bottles were immediately placed in an electrically driven tester, heated by steam and run for five, two and one minutes, making two fillings with hot water. The bottles were then placed in a water bath at 130°F. and after standing five to ten minutes they were read to the extremes of the fat column, making the readings to 0.05 per cent.

### *Results obtained*

The average of the results obtained by carrying out the experiments as outlined above are given in table 6. The results in detail are given in the appendix.

TABLE 6

*Comparison of average results by the Babcock and gravimetric methods*

| BREED AND NUMBER OF COW | AGE AT FRESHENING | NUMBER OF SAMPLES | LACTOMETER READING | PER CENT FAT | | | AVERAGE BY GRAVIMETRIC METHOD | AVERAGE OF ALL BABCOCK READINGS ABOVE AVERAGE GRAVIMETRIC | AVERAGE OF DIFFERENCES† |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Average of readings by No. 8, 10 per cent bottles | Average of Babcock readings by No. 8, 8 per cent bottles | Average* of all Babcock readings 8 per cent bottles | | | |
| | *years* | | | | | | | | |
| Jersey, 13 | 15 | 30 | 31.4 | | 4.937 | 4.923 | 4.861 | 0.062 | ±0.065 |
| Jersey, 268 | 2 | 22 | 31.6 | | 6.310 | 6.293 | 6.205 | 0.078 | ±0.078 |
| Guernsey, 98 | 9 | 22 | 30.6 | | 4.135 | 4.125 | 4.068 | 0.057 | ±0.057 |
| Guernsey, 267 | 2 | 30 | 32.5 | 5.432 | 5.412 | 5.390 | 5.301 | 0.089 | ±0.089 |
| Ayrshire, 230 | 4 | 14 | 27.3 | | 3.179 | 3.166 | 3.119 | 0.047 | ±0.051 |
| Ayrshire, 243 | 3 | 26 | 32.5 | | 4.583 | 4.563 | 4.512 | 0.052 | ±0.053 |
| Holstein, 161 | 6 | 26 | 31.9 | | 3.350 | 3.337 | 3.303 | 0.034 | ±0.041 |
| Holstein, 269 | 2 | 20 | 29.4 | 3.364 | 3.337 | 3.326 | 3.280 | 0.046 | ±0.047 |
| Average | | | | | 4.514 | 4.498 | 4.438 | 0.060 | ±0.062 |

* Average of 6 readings by 3 individuals

† See table 1.

The results given in table 6 show that the average of all the Babcock readings is 0.060 per cent above the average for all the gravimetric results. The average of the differences between the

average of all the Babcock readings and the gravimetric results on each sample of ±0.062 per cent is only slightly higher since most of the Babcock readings are above the gravimetric results. The differences, considering each sample, vary from −0.04 per cent to +0.16 per cent. The Babcock readings mentioned in these figures are the average of six readings (in some cases twelve) by three individuals and this would tend to reduce the variation.

However, the average of the six readings by one individual only varied −0.09 per cent to −0.17 per cent from the gravimetric method, while for single tests the variation was from −0.14 per cent to +0.19 per cent. There were, of course, only a few of these extreme values as indicated by the average of ±0.062. Of the reading on the same sample by any one of the individuals 94.88 per cent agree within 0.05 per cent of the average for that individual. In other words, on the average only 5.12 per cent of the readings on a sample by any one individual varied over 0.10 per cent.

### *Influence of breed and stage of lactation*

The results in table 6 indicate some relationship between the excess of the Babcock readings over the gravimetric determinations and the breed. With the Channel Island breeds this excess is slightly higher than with the other breeds which may be accounted for in part by the smaller numbers of minute fat globules with the former breeds, as a result of which less fat is left in the liquid below the fat column. A few determinations of the residual fat showed there was somewhat less with these breeds as indicated in table 7. Part of the excess reading is due to these breeds having a higher per cent of fat in the samples since some of the factors which cause losses and gains to the fat columns vary with the reading as will be shown later and the balance of these variable factors causes an increase in the reading proportional to the per cent fat present.

The stage of lactation seemed to have a slight influence on the excess of the Babcock readings and in the case of the Holstein cows 161 and 269 and Ayrshire 243, it was quite noticeable.

A comparison of the average of all the cows for the first three months of their lactation periods with the last three months showed the excess to be 0.013 per cent higher in the first three months. Larger excess readings in the first part of the lactation period can also be explained by a smaller number of minute fat globules at that time. This is indicated quite markedly in table 7 with the Holstein cows. These are two different cows than those mentioned above. The variation in the per cent of fat was not sufficient to have much influence.

TABLE 7

*Influence of breed and stage of lactation on amount of residual fat. Average of four determinations*

| BREED AND NUMBER OF COW | FIRST PART OF LACTATION PERIOD | | LAST PART OF LACTATION PERIOD | |
|---|---|---|---|---|
| | Samples | Bottle reading | Samples | Bottle reading |
| | | *per cent* | | *per cent* |
| Jersey, 13 | 1, 2, 7, 8 | 0.117 | 27, 28, 29, 30 | 0.127 |
| Jersey, 268 | 5, 6, 9, 10 | 0.111 | | |
| Holstein, 161 | 1, 2, 7, 8 | 0.130 | | |
| Holstein, 173 | 1, 2, 3, 4 | 0.116 | 5, 6, 7, 8 | 0.191 |
| Holstein, 283 | 1, 2, 3, 4 | 0.124 | 5, 6, 7, 8 | 0.170 |
| Average due to lactation period | | 0.119 | | 0.163 |

### *Results by individual readers*

As stated in the introduction, there is a difference in the readings of the same tests by different individuals. On the same sample the difference of the averages of the readings of the six tests between different individuals was as high as 0.15 per cent. On the average of a number of tests the greatest difference was between readers 8 and 19 which amounted to 0.085 per cent as indicated in table 8.

This table shows how the average results by the different readers compare with the average of the gravimetric determinations. The results by reader 8, who read all the tests, are also given on the same samples since the difference between the average of the reader's results and the average by the gravi-

metric method might be due to an actual difference in these samples and not to his method of reading: a second reader's results on the same samples would indicate to some extent, if a difference in the samples existed.

The reason for the discrepancy in readings between different individuals may be due to several reasons, among which are a

TABLE 8

*Comparison of gravimetric method with average of all Babcock readings by different individuals*

| INDIVIDUAL'S NUMBER | NUMBER OF COMPARISONS* | NUMBER OF TESTS | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC RESULTS | AVERAGE OF ALL READINGS ON SAME TESTS BY NO. 8 ABOVE GRAVIMETRIC RESULTS |
|---|---|---|---|---|
| 1 | 32 | 210 | 0.015 | 0.055 |
| 2 | 29 | 198 | 0.064 | 0.071 |
| 3 | 35 | 294 | 0.051 | 0.071 |
| 4 | 32 | 252 | 0.065 | 0.085 |
| 5 | 11 | 132 | 0.018 | 0.053 |
| 6 | 32 | 246 | 0.057 | 0.079 |
| 7 | 55 | 312 | 0.051 | 0.065 |
| 8 | 190 | 1,476 | 0.076 | 0.076 |
| 9 | 30 | 282 | 0.049 | 0.057 |
| 12 | 5 | 60 | 0.112 | 0.092 |
| 13 | 31 | 234 | 0.070 | 0.073 |
| 14 | 6 | 48 | 0.073 | 0.092 |
| 15 | 10 | 60 | 0.109 | 0.116 |
| 16 | 35 | 222 | 0.006 | 0.084 |
| 19 | 8 | 48 | 0.015 | 0.100 |
| 21 | 6 | 36 | 0.073 | 0.112 |
| 22 | 6 | 36 | 0.063 | 0.120 |

*Individuals reading in less than 5 comparisons not included.

difference in eyesight, reading to different points on the upper meniscus and not having the eye on a level with the ends of the fat column when taking the readings.

In an attempt to determine which one might be the important reason, readers 1, 16 and 19 who differed the most from reader 8 were subjected to a series of readings in comparison with reader 8. A series of twelve tests of different per cents of fat were read through twice to see if the reader could check himself. The tests were then read in front of a mirror according to the

method recommended by Hunziker (21) to see if the reader was getting his eye on a level with the ends of the fat column. Finally the tests were read with glymol, since if two readers then agreed more closely, it would indicate they were not reading to the same point on the meniscus. The average results presented in table 9 indicate that these four readers read consistently and that their readings varied very little because of not having their eyes on a level with the ends of the fat column although

TABLE 9

*Tests with individual readers. Average of twelve different readings*

| NUMBER OF READER | FIRST READING | SECOND READING | READING BEFORE MIRROR | READING WITH GLYMOL | LOWERING OF READING DUE TO GLYMOL |
|---|---|---|---|---|---|
| 8 | 4.58 | 4.57 | | 4.43 | 0.15 |
| 1 | 4.53 | 4.53 | | 4.38 | 0.15 |
| Difference | 0.05 | 0.04 | | 0.05 | 0 |
| 8 | 4.03 | 4.02 | 4.04 | 3.90 | 0.13 |
| 16 | 3.92 | 3.91 | 3.92 | 3.83 | 0.09 |
| Difference | 0.11 | 0.11 | 0.12 | 0.07 | 0.04 |
| 8 | 5.08 | 5.08 | 5.08 | 4.93 | 0.15 |
| 16 | 4.96 | 4.96 | 4.99 | 4.86 | 0.10 |
| Difference | 0.12 | 0.12 | 0.09 | 0.07 | 0.05 |
| 8 | 5.04 | 5.05 | 5.05 | 4.90 | 0.14 |
| 19 | 4.96 | 4.96 | 4.95 | 4.90 | 0.06 |
| Difference | 0.08 | 0.09 | 0.10 | 0 | 0.08 |

this is believed to have had some influence. There was, of course, some variation between single readings on the same test, but the variation was under $\pm 0.015$ on an average of all the readings both as between the first and second readings and between the second reading and that made before the mirror. The highest average variation by one individual was $\pm 0.033$, which was made by no. 1. Not reading to the same place on the upper meniscus was probably the biggest reason for the difference in readings, though this does not wholly explain the discrepancies.

It is believed that the readers who made the lower readings were not reading to the top of the upper meniscus. This opinion is held because the average results by the majority of the readers were at the higher figures. There seems to be no good reason why one should over read the tests. There is sometimes a thin film above the top of the meniscus observed in direct light but this should be easily distinguished. The results by persons who had had considerable training in making exact chemical determinations agree with the higher readings. Also the depth of the upper meniscus calculated from a few readings by Webster and Gray (22) and Smith (23) agrees with the value assigned to it by the persons making the higher readings, which indicates that these investigators were reading to a similar point. If the lower readings were not made to the top of the upper meniscus, the excess of the Babcock readings over the gravimetric determinations would be slightly more than 0.060 per cent, which included the readings by all individuals.

Babcock (24) states that the reading should be taken where the upper surface of the fat meets the side of the tube and not from the surface of the fat in the center of the tube nor from the bottom of the dark line caused by the refraction of the curved surface. Schrott-Fiechtl (25) considers that the main source of error in rapid milk tests is reading off of the fat columns.

### V. LOSSES AND GAINS TO THE FAT COLUMN

A study was made of the losses and gains to the fat column in order to determine their value and the balance between them. The meniscuses were studied separately from these losses and gains. The balance should show how much the readings would be below the correct per cent of fat as determined by the gravimetric method, if the fat columns had no meniscuses.

The losses and gains studied were: (1) the residual fat, that is, the fat left in the liquid below the fat column, (2) the weight of sample delivered by the pipette, (3) the impurities in the fat in the neck of the bottle and (4) the effect of reading at 130°F., which is above the temperature at which the density of butterfat is 0.9. The loss of glycerol and fatty acids and the variation

in the density of butterfat would also have an effect. The loss due to the former was calculated from results by others.

The value of the excess readings due to the meniscuses was determined and also calculated. It could then be shown how much this value offset the balance of the other losses and gains to the fat column. The calculated value would also be a further indication as to what point is the top of the meniscus.

### *Residual fat*

To determine the residual fat the necks of four bottles were broken off and the liquid below the fat column poured into a separatory funnel. This liquid was extracted with two portions of ethyl ether, first 150 cc. and then 75 cc. the ethereal extract

TABLE 10

*Residual fat*

| SAMPLE NUMBER | WEIGHT FAT FROM 4 BOTTLES | BOTTLE READING | SAMPLE NUMBER | WEIGHT FAT FROM 4 BOTTLES | BOTTLE READING | SAMPLE NUMBER | WEIGHT FAT FROM 4 BOTTLES | BOTTLE READING |
|---|---|---|---|---|---|---|---|---|
| | *grams* | *per cent* | | *grams* | *per cent* | | *grams* | *per cent* |
| 13- 1 | 0.0715 | 0.099 | 268–10 | 0.0635 | 0.088 | 173–5 | 0.1675 | 0.233 |
| 13- 2 | 0.0895 | 0.124 | 243–15 | 0.1055 | 0.147 | 173–6 | 0.1628 | 0.226 |
| 13- 7 | 0.0790 | 0.110 | 243–16 | 0.0945 | 0.131 | 173–7 | 0.1095 | 0.152 |
| 13- 8 | 0.0960 | 0.133 | 161- 1 | 0.0880 | 0.122 | 173–8 | 0.1100 | 0.153 |
| 13- 9 | 0.0475 | 0.066 | 161- 2 | 0.0900 | 0.125 | 283–1 | 0.0705 | 0.098 |
| 13–11 | 0.0660 | 0.092 | 161- 7 | 0.0885 | 0.123 | 283–2 | 0.0625 | 0.087 |
| 13–27 | 0.0795 | 0.110 | 161- 8 | 0.0935 | 0.130 | 283–3 | 0.1350 | 0.188 |
| 13–28 | 0.0890 | 0.124 | 161- 9 | 0.0750 | 0.104 | 283–4 | 0.0885 | 0.123 |
| 13–29 | 0.1070 | 0.149 | 161–11 | 0.1000 | 0.139 | 283–5 | 0.1375 | 0.191 |
| 13–30 | 0.0895 | 0.124 | 173- 1 | 0.0830 | 0.151 | 283–6 | 0.1090 | 0.151 |
| 268–5 | 0.0930 | 0.129 | 173- 2 | 0.0780 | 0.108 | 283–7 | 0.1280 | 0.178 |
| 268–6 | 0.0800 | 0.111 | 173- 3 | 0.0950 | 0.132 | 283–8 | 0.1140 | 0.158 |
| 268–9 | 0.0825 | 0.115 | 173- 4 | 0.0778 | 0.108 | | | |
| Average of all..... | | | | ..... | | | 0.0947 | 0.132 |

washed twice with water, evaporated to dryness, the residue taken up with petroleum ether (boiling point below 60°C.) filtered, and the weight of the fat determined. A similar method has been used for the same purpose with ice cream tests (26).

This method for determining the residual fat was checked up by subjecting some skim milk to the Babcock procedure and

then determining all the fat as above. The fat was also determined by extracting the same amount of skim milk in a separatory funnel by the Roese-Gottlieb method in order to determine the actual amount present. On three comparisons in duplicate the per cent recovered by the above method ranged from 90.5 to 98.8 with an average of 94.8.

The residual fat found in 38 samples of milk varied from 0.066 per cent to 0.233 per cent calculated as reading on the bottle graduation, and averaged 0.132 per cent as is shown in table 10. While this variation is large, there are very few extreme values. The variation is probably due to a variation in the size of the fat globules.

*Weight of sample delivered by pipette*

The pipettes used were calibrated to deliver 17.6 cc. of water at 20°C. in five to eight seconds, as specified by the American Dairy Science Association (27). The pipettes were allowed to drain two or three seconds after emptying and then they were touched against the inside of the neck of the bottle. They were kept particularly clean so as to drain readily.

The amount of milk delivered was determined by weighing the bottles empty and after adding the milk. On thirty-four samples in duplicate the weight delivered at 70°F. varied from 17.886 grams to 17.964 grams with an average of 17.924 grams. Although the specific gravity of the milk has some influence on the amount delivered, there are other factors which affect it, since quite a few weighings did not seem to vary with the specific gravity. The condition of the milk is probably a big factor.

The above figures show that on an average there were 0.076 gram less milk delivered than there should have been. This would make an error of 0.42 per cent of the reading. On the average reading of 4.51 per cent this would amount to 0.019 per cent on the bottle graduation.

The influence of the temperature on the amount of milk delivered was determined by weighing the milk delivered at 70°F. and at 115°F. On two samples in duplicate the average delivered at 70°F. was 17.937 grams and at 115°F. 17.814 grams.

At 115°F. the amount delivered was 0.186 gram low or 1.03 per cent of the reading. On the average reading of 4.51 per cent this would amount to 0.046 per cent.

*Impurities in fat column*

The fat column contains a certain amount of impurities as is shown by its cloudiness. This is due mainly to water and acid, which have become emulsified into the fat.

To determine the impurities in the fat column, samples of the fat were removed from the necks of test bottles by means of a pipette, care being taken not to obtain any of the residual liquid. The per cent was determined by extracting 1 to 1.5 grams of this fat by the Roese-Gottlieb method. The ammonia was omitted as it was deemed unnecessary since there is no curd to dissolve and, in addition, ammonium salts of fatty acids would be formed which are soluble in the alcoholic mixture. In addition the flasks were rinsed between extractions with 25 cc. petroleum ether.

The per cent of impurities in fifteen samples, as given in table 11, varied from 0.036 per cent to 1.23 per cent with an average of 0.78 per cent. Most of the values were quite close to the average. On the average reading of 4.51 per cent the average error in reading due to impurities would be 0.035 per cent as bottle reading.

*Volatile fatty acids and glycerol*

The loss due to volatile fatty acids and glycerol was not determined, since, judging from the results by Hunziker (28) on cream, it would be of little consequence, and because the method of determination is long and permits of considerable variation in results. A few determinations were made by titrating the fat from the determinations of the per cent of impurities. Only slight traces of sulphuric acid were present. On the assumptions that all the non-volatile fatty acids are present in the fat in the neck, and that the saponification of the volatile and non-volatile acids proceed at a rate proportional to their relative

amounts, this acidity was calculated, on the average of a few determinations, to represent volatile acids and glycerol to the extent of 0.020 per cent, expressed as bottle reading. These figures, however, are only considered of value in that they corroborate the results which were obtained by calculation from Hunziker's results on cream.

*Temperature of reading test*

The average density of butterfat has been found at this station[2] to be 0.8974 at 120°F. It was also found that the density varied 0.00038 per degree Fahrenheit. From this it is calculated that the density of butterfat is 0.9000 at 113°F.; accordingly readings made at 130°F. would be made 17°F. too high.

Since the change in the reading of a fat column due to increase of temperature is caused by expansion, it varies inversely as the density. Therefore

$$\frac{\text{Reading at 113°F.} - \text{Density of fat at 130°F.} - 0.8935}{\text{Reading at 130°F.} - \text{Density of fat at 113°F.} - 0.9000}$$

or reading at 113°F. equals 0.9929 × reading at 130°F. The error due to temperature of reading the test is then found by taking 0.71 per cent (100 per cent − 99.29 per cent) of the results at 130°F. The error due to reading a 4.51 per cent test would be 0.032 per cent.

*Balance between losses and gains*

The balance of the losses and gains to the fat column, expressed as per cent as read on the bottle graduation is given in table 11 for fifteen individual samples, and the balance is also given calculated on the basis of the average reading of 4.51 per cent. On the average of the individual samples the tests would read 0.113 per cent low if the meniscuses were not included. On the basis of the 4.51 per cent reading the results would be 0.106 per cent low. In other words if the ends of the fat colums were flattened the results would be below the true amount

[2] Unpublished data.

TABLE 11

*Balance between losses and gains*

| NUMBER OF SAMPLE | BABCOCK READINGS BY NO. 8 | AMOUNT ABOVE GRAVIMETRIC METHOD | LOSSES TO FAT COLUMN, AS PER CENT BOTTLE READING, DUE TO | | | | PER CENT IMPURITIES IN FAT COLUMN | GAINS TO FAT COLUMN AS PER CENT BOTTLE READING, DUE TO | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Residual fat | Weight of sample (0.42 per cent of reading) | Fatty acids and glycerol* | Total | | Impurities | Reading at 130°F. (0.71 per cent reading) | Total | Balance |
| 13–27 | 4.98 | 0.13 | 0.110 | 0.021 | 0.024 | 0.155 | 0.91 | 0.045 | 0.035 | 0.080 | −0.075 |
| 13–28 | 5.12 | 0.10 | 0.124 | 0.022 | 0.025 | 0.171 | 0.90 | 0.046 | 0.036 | 0.082 | −0.089 |
| 13–30 | 4.70 | 0.09 | 0.124 | 0.020 | 0.023 | 0.167 | 0.82 | 0.039 | 0.033 | 0.072 | −0.095 |
| 268– 6 | 4.76 | 0.10 | 0.111 | 0.020 | 0.023 | 0.154 | 0.77 | 0.037 | 0.034 | 0.071 | −0.083 |
| 268– 9 | 7.51 | 0.06 | 0.115 | 0.032 | 0.036 | 0.183 | 1.09 | 0.082 | 0.053 | 0.135 | −0.048 |
| 243–15 | 4.43 | 0.06 | 0.147 | 0.019 | 0.021 | 0.187 | 0.78 | 0.035 | 0.031 | 0.066 | −0.121 |
| 173– 2 | 2.20 | 0.03 | 0.108 | 0.009 | 0.011 | 0.128 | 0.85 | 0.019 | 0.016 | 0.035 | −0.093 |
| 173– 3 | 2.31 | 0.05 | 0.132 | 0.010 | 0.011 | 0.153 | 0.76 | 0.018 | 0.016 | 0.034 | −0.119 |
| 173– 4 | 2.45 | 0.06 | 0.108 | 0.010 | 0.012 | 0.130 | 0.81 | 0.020 | 0.017 | 0.037 | −0.093 |
| 173– 6 | 4.93 | 0.10 | 0.226 | 0.021 | 0.024 | 0.271 | 0.43 | 0.021 | 0.035 | 0.056 | −0.215 |
| 173– 8 | 4.08 | 0.06 | 0.153 | 0.017 | 0.020 | 0.190 | 0.36 | 0.015 | 0.029 | 0.044 | −0.146 |
| 283– 3 | 1.83 | 0.05 | 0.188 | 0.008 | 0.009 | 0.205 | 0.76 | 0.014 | 0.013 | 0.027 | −0.178 |
| 283– 4 | 2.73 | 0.08 | 0.123 | 0.011 | 0.013 | 0.147 | 0.67 | 0.018 | 0.019 | 0.037 | −0.110 |
| 283– 6 | 5.93 | 0.09 | 0.151 | 0.025 | 0.028 | 0.204 | 1.23 | 0.073 | 0.042 | 0.115 | −0.089 |
| 283– 8 | 2.81 | 0.10 | 0.158 | 0.012 | 0.013 | 0.183 | 0.54 | 0.015 | 0.020 | 0.035 | −0.148 |
| Average of the 15 samples..... | 4.05 | 0.076 | 0.139 | 0.017 | 0.020 | 0.175 | 0.78 | 0.033 | 0.029 | 0.062 | −0.113 |
| Average of all samples..... | 4.51 | 0.076 | 0.132 | 0.019 | 0.022 | 0.173 | 0.78 | 0.035 | 0.032 | 0.067 | −0.106 |

* Calculated from average percentage of loss on cream tests of 0.048 per cent as determined by Hunziker.

by about 0.11 per cent on the average. The amount a reading would be low could be calculated from a formula as follows.[3] (0.78 per cent + 71 per cent − 0.42 per cent − 48 per cent) × reading − 0.132 or more simply, 0.59 × reading − 0.132.

As indicated by this formula the balance between the losses and gains will depend somewhat on the per cent of fat present in the sample since four of the factors which effect this balance vary with the reading. The balance of these variable factors is 0.59 per cent of the reading. This means that the Babcock results on a rich milk compared with the gravimetric determinations will be 0.0059 per cent higher for each per cent of fat, than the results on a poor milk. On the difference between the extreme average readings as given in table 6 this would amount to 0.018 per cent, which explains in part why the tests of the samples from the Channel Island breeds have a greater excess reading over the gravimetric method than the samples from the other breeds.

### *The meniscuses*

By reading to the extreme ends of the fat columns the readings are increased due to both the upper and lower meniscuses. The greater part of this increase is due to the upper meniscus. The value of the meniscus depends on the width of the neck of the bottle. If the length of the graduation is made shorter, which will increase the width of the neck, the depth of the meniscus will increase. At the same time the graduations get closer

[3] Some of these figures for the different losses and gains should be considered only as close approximations, since there are evident errors in the calculations. These errors are not taken into consideration as they would only complicate the discussion and would not lead to any advantage for the purpose here. The calculation of the gain to the reading due to impurities, for example, is made on the assumption that the impurities have the same density as the fat, while undoubtedly, the density is above 1.0 since they consist mostly of water and acid. Also the gain due to reading at 130°F. is calculated from values of the density of fat based on water weighed in air while the calibration of the necks of the bottles is based on the true cubic centimeter. The errors in these two calculations, however, tend to neutralize each other. There are also other errors of still less consequence.

together which augments the value of the meniscus when expressed as per cent, as read on the necks of the bottles.

The relation between the width of tubes and the depth of meniscuses of fat was determined at 120°F. by measuring the meniscuses in short glass tubes of different diameters, by means of a microscope with a micrometer eyepiece. The values of the meniscuses seemed slightly higher than when measured by the eye but this should not affect the relation. The results show that the depth of the meniscus varies directly as the width of the tube but the amount of variation diminishes and approaches zero as the width of tube increases. The relation was also worked out on the basis of per cent bottle reading and the results show the same variation but the amount of variation increases as the width of the tube increases. These relations are shown diagrammatically in chart I.

The effect of different lengths of graduation upon the readings is shown in the comparison of the results in the 8 per cent and 10 per cent bottles as given in table 6. The length of graduation of the 8 per cent bottles equalled about 70 mm. while for the 10 per cent bottles it equalled 57 mm. for 8 per cent on the graduation. The readings in the 10 per cent bottles were 0.023 per cent higher than in the 8 per cent bottles on 50 comparisons of six tests each. Ten per cent bottles of considerably shorter graduations than the above have been used in the past. These would, of course, introduce quite a large error into the Babcock readings.

In order to determine the excess reading due to both meniscuses on the 8 per cent bottles which were used in this work, pure butterfat was weighed out into the necks of the bottles after they had been partially filled with water, the bottles whirled in the Babcock tester and then read at 130°F. from a water bath. The temperature of the contents of the bottles were kept above 130°F. up to the time they were placed in the bath in order that the lower meniscus would be of the same form as that usually obtained in testing. The form of the lower meniscus would have some effect on the value of the excess reading due to the meniscuses. On an average of twelve comparisons the excess

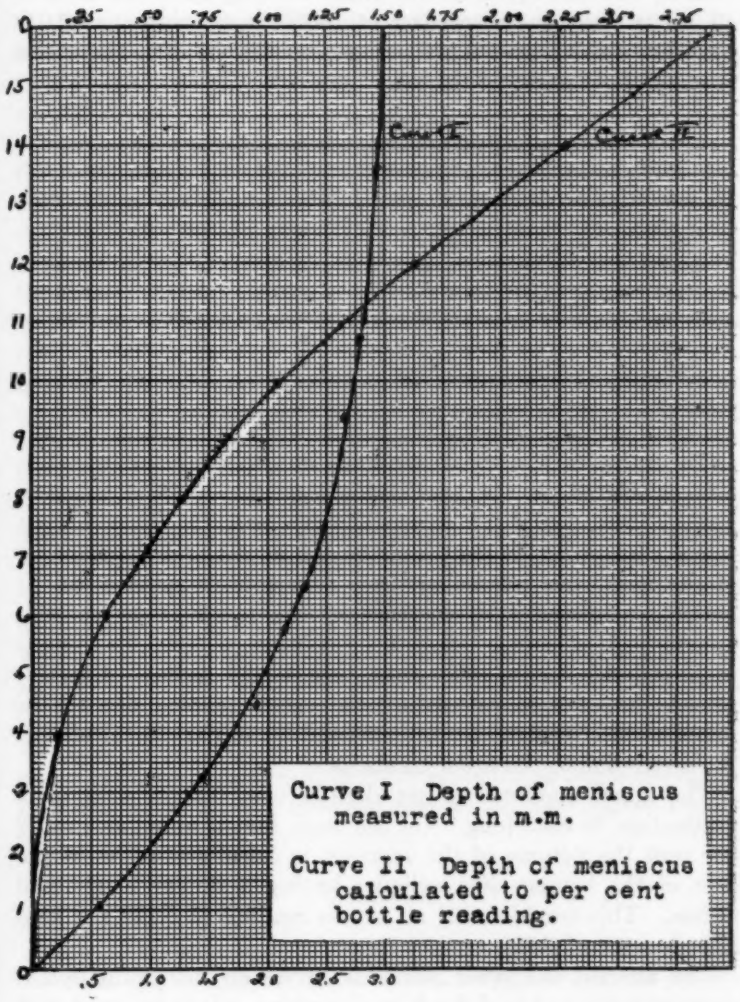


CHART SHOWING RELATION BETWEEN WIDTH OF TUBE AND DEPTH OF MENISCUS

reading was 0.218 per cent (as bottle reading) as shown in table 12. The error due to reading at 130°F. is calculated[4] as 0.039 per cent which leaves 0.179 per cent as the value of the excess reading, determined in this way.

TABLE 12

*Showing excess reading due to meniscuses*

| ACTUAL READINGS | THEORETICAL READINGS | DIFFERENCES | ACTUAL READINGS | THEORETICAL READINGS | DIFFERENCES |
|---|---|---|---|---|---|
| 3.40 | 3.12 | 0.28 | 5.80 | 5.59 | 0.21 |
| 5.40 | 5.20 | 0.20 | 5.20 | 4.96 | 0.24 |
| 3.85 | 3.66 | 0.19 | 5.40 | 5.19 | 0.21 |
| 4.80 | 4.58 | 0.22 | 4.80 | 4.59 | 0.21 |
| 4.40 | 4.16 | 0.24 | 5.30 | 5.12 | 0.18 |
| 3.30 | 3.09 | 0.21 | 4.65 | 4.43 | 0.22 |
| Average..... | | | 4.69 | | 0.218 |

The value of the excess readings due to the meniscuses was also calculated on the assumption that they have a spherical form. This should be approximately true in these narrow tubes. Knowing the depths of the meniscuses and the diameter of the neck, the volume of these segments of spheres can be readily calculated. In the case of the lower meniscus, this volume will, of course, have to be subtracted from the volume of a cylinder having the same height and radius. For this reason the error in calculating the excess reading due to the upper meniscus might be compensated for in part in calculating the excess due to the lower meniscus.

The upper meniscus covers slightly over 0.2 per cent on a graduation 70 mm. long. On the basis that it amounts to 0.22 per cent the volume of the segment is calculated to be 58 per cent of the volume of a cylinder having a similar height and radius. This would mean an excess reading of 0.129 per cent (58 per cent of 0.22).

The amount the lower meniscus covers on the graduation is quite variable and is difficult to determine. It is believed that

[4] In this calculation the value of the density of butter fat is based on a true cubic centimeter.

0.10 per cent is a fair average value for tests as carried out in this work and on this basis the excess reading is calculated to be 0.048 per cent. The total excess reading would be 0.177 per cent (0.129 + 0.048) which agrees quite closely with the experimental value.

Since including the meniscuses increases the readings 0.179 per cent, this more than counterbalances the loss of 0.106 per cent due to the balance of the other losses and gains to the fat column, as calculated from the average results. The difference between these would mean an excess reading due to reading to the ends of the fat column of 0.073 per cent (0.179 per cent minus 0.106 per cent) which is in close agreement with the average excess reading of 0.076 per cent calculated from the difference between the average Babcock readings and the average gravimetric results as calculated from readings by the same individual who determined the value of the excess readings due to the meniscuses.

This agreement only goes to show that the losses and gains as determined are near the true amounts. It is no further indication as to what point is really the top of the upper meniscus, since the value of excess reading due to the meniscuses was determined by the readings of tests and the same error as to what point is the top of the meniscus, would be present in both results. However, since the value of the excess reading due to the meniscuses agrees with the value calculated on the assumption that the meniscuses are spherical, there is this further indication that the higher readings were made to the top of the upper meniscus and that the Babcock test would give higher results than the gravimetric determination.

## SUMMARY

Since it is the opinion of some that reading the Babcock test for milk to the extreme ends of the fat columns gives results which are higher than the true amount of fat present, a study was made of the test to find out how results obtained by the present method of procedure compared with the gravimetric

determinations and also to determine the influence of certain factors on the test.

From some preliminary work it was decided that to obtain the most satisfactory tests, the correct amount of acid of not less than 1.82 specific gravity, should be added preferably at 70°F. or lower, and after mixing the bottles whirled immediately in a smooth running tester (heated if room is cold) at the specified speed. Whirling directly after mixing is one of the commonly neglected factors in obtaining practically clean fat columns.

The correct amount of acid should give a light yellow to golden yellow fat column and is best determined by trial. Tests which have darker fat columns or which have been allowed to stand between mixing and whirling are apt to have more sediment present. This is because there is more suspended material formed in the residual liquid and this may get up into the fat column. Any factor which produces practically colorless fat columns, as acid of 1.81 specific gravity, etc., tends to g ve slightly low results.

A comparison between the results by the Babcock method and the gravimetric (Roese-Gottlieb) method was made on 2 samples of milk a month during the lactation period of 8 cows from 4 different breeds. Six Babcock tests (12 with 2 cows) were made in 8 per cent bottles (10 per cent bottles also used with 2 cows) on each sample and these were read by three members of the Dairy Department at the Iowa State College. On 190 samples the average of all Babcock readings was 0.060 per cent above the average of all gravimetric results. The differences between the average of all Babcock readings (6 tests by 3 individuals) and the gravimetric results on each sample varied from −0.04 per cent to +0.16 per cent. With single tests the variation was from −0.14 per cent to +0.19 per cent. On the average, only 5.12 per cent of the six readings on one sample by any one individual varied over 0.10 per cent.

The excess of the Babcock readings over the gravimetric results was greatest with the samples from the Channel Island breeds and it was also slightly higher on the average during the first part of the lactation period, this being particularly notice-

able with the Holstein cows. The greater excess readings may be partly explained by the smaller proportion of minute fat globules present. A few determinations of the residual fat showed the expected relationship. Variation in the per cent of fat in the samples is also a factor influencing the excess reading, since the balance of some of the losses and gains to the fat column is proportional to the per cent of fat present.

There was considerable difference between the readings by a few of the individual readers. This amounted to as much as 0.15 per cent on the average of the six readings on a single sample. On the average of a number of comparisons the difference between readers was as high as 0.085 per cent.

From a study of the readers showing the greatest disagreement, it was concluded that the principal reason for the difference was due to reading to different points on the upper meniscus. It is also believed for reasons given, that the higher readings were made to the top of the upper meniscus and the others to a lower point.

The losses to the fat columns were determined to be 0.132 per cent expressed as bottle reading (average of 38 determinations), due to residual fat, and 0.42 per cent of the reading (average of 68 determinations) due to less than 18 grams being delivered by the pipette. The loss due to fatty acids and glycerol was taken to be 0.48 per cent of the reading, this being the value determined by Hunziker for cream. The gains were determined to be 0.78 per cent of the reading (average of 15 determinations) due to impurities in the fat column and 0.71 per cent of the reading due to reading at 130°F. which is above the temperature at which the density of butterfat is 0.9. On the basis of the average test of 4.51 per cent the balance between these losses and gains would be $-0.106$ per cent (0.78 per cent + 0.71 per cent − 0.42 per cent − 0.48 per cent) × (4.51 − 0.132) which means that excluding the meniscuses the reading would be that much too low. The balance depends to some extent on the per cent of fat present, since most of the losses and gains vary with the reading.

The value of the excess reading due to including the meniscuses was found to be 0.179 per cent by weighing pure butterfat into the necks of test bottles and determining the excess reading over the theoretical value. This value was checked by results calculated on the assumption that the meniscuses are spherical.

The difference between excess reading due to the meniscuses and the low reading due to the balance of the other losses and gains is 0.073 per cent (0.179 per cent minus 0.106 per cent) which agrees quite closely with 0.076 per cent, the difference between the average of the Babcock readings and the average of the gravimetric results, the Babcock readings being made by the same individual who determined the value of the excess reading due to the meniscuses. This shows that the losses and gains, as determined, are near the true values. Since the calculated value for the excess reading due to the meniscuses agrees with the determined value, this is a further indication that the higher readings were made to the top of the upper meniscus.

## CONCLUSIONS

1. The Babcock test for milk when read from the top of the upper meniscus to the bottom of the lower meniscus gave results which were higher than those obtained by the gravimetric (Roese-Gottlieb) method. On the average of 190 comparisons, as carried out in the work reported, the difference amounted to 0.060 per cent.

2. There was a considerable variation in the readings on the same sample by a few individuals; this was largely due to reading to different points on the upper meniscus and it is believed that the higher readings were made to the top of the upper meniscus.

3. The breed of the cows and the stage of lactation had a small influence on the excess of the Babcock results over the gravimetric determinations. This influence is due in part to the variation in the size of the fat globules and in part to the variation in the per cent fat present in the sample tested.

4. The amount of fat left in the liquid below the fat column is quite variable and on the average equalled 0.13 per cent expressed as reading on the neck of the test bottles.

5. There were impurities in the fat column that on the average amounted to 0.78 per cent of the reading.

6. The Babcock test would read about 0.11 per cent low, depending somewhat on the per cent of fat in the sample, if the meniscuses were not included in the reading. This is shown by a balance of the losses and gains to the fat column.

7. The value of the gain to readings due to the meniscuses, as determined by one of the readers, more than offsets this low reading, which is in agreement with the first conclusion.

TABLE A

*Jersey cow 13; age at freshening 14 years, 10 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 12 Babcock readings by individuals | | | Average of all Babcock readings | Gravimetric method | | | | |
| | | | A | B | C | | | | A | B | C |
| 1 | 3/26/16, p.m. | | 4.59 | 4.59 | 4.60 | 4.59 | 4.57 | 0.02 | 3 | 9 | 8 |
| 2 | 3/27/16, a.m. | | 4.83 | 4.85 | 4.86 | 4.85 | 4.89 | −0.04 | 7 | 5 | 8 |
| 3 | 3/27/16, p.m. | | 4.40 | 4.38 | 4.40 | 4.39 | 4.34 | 0.05 | 6 | 4 | 8 |
| 4 | 3/28/16, a.m. | | 4.49 | 4.48 | 4.50 | 4.49 | 4.47 | 0.02 | 6 | 4 | 8 |
| 5 | 4/26/16, a.m. | 32.0 | 4.43 | 4.40 | 4.43 | 4.42 | 4.36 | 0.06 | 9 | 6 | 8 |
| 6 | 4/27/16, p.m. | 30.5 | 5.50 | 5.50 | 5.51 | 5.50 | 5.54 | −0.04 | 3 | 10 | 8 |
| 7 | 4/27/16, a.m. | 32.5 | 4.16 | 4.22 | 4.19 | 4.19 | 4.16 | 0.03 | 5 | 12 | 8 |
| 8 | 4/28/16, p.m. | 32.5 | 5.17 | 5.17 | 5.18 | 5.17 | 5.13 | 0.04 | 4 | 7 | 8 |
| 9 | 5/28/16, p.m. | 32.0 | 5.48 | 5.49 | 5.51 | 5.49 | 5.56 | −0.07 | 1 | 9 | 8 |
| 10 | 5/29/16, a.m. | 31.0 | 4.78 | 4.77 | 4.80 | 4.78 | 4.87 | −0.09 | 3 | 5 | 8 |
| 11 | 6/26/16, p.m. | 31.0 | 5.08 | 5.04 | 5.11 | 5.08 | 5.15 | −0.07 | 7 | 5 | 8 |
| 12 | 6/27/16, a.m. | 32.5 | 4.37 | 4.35 | 4.39 | 4.37 | 4.39 | −0.02 | 2 | 7 | 8 |
| 13 | 7/25/16, p.m. | 30.0 | 4.59 | 4.60 | 4.60 | 4.60 | 4.54 | 0.06 | 4 | 7 | 8 |
| 14 | 7/26/16, a.m. | 30.5 | 3.89 | 3.90 | 3.89 | 3.89 | 3.85 | 0.04 | 9 | 12 | 8 |
| 15 | 9/3/16, p.m. | 30.0 | 5.25 | 5.20 | 5.25 | 5.23 | 5.19 | 0.04 | 9 | 7 | 8 |
| 16 | 9/4/16, a.m. | 31.0 | 4.87 | | 4.89 | 4.88 | 4.84 | 0.04 | 3 | | 8 |
| 17 | 9/25/16, p.m. | 30.0 | 5.14 | 5.14 | 5.17 | 5.15 | 5.15 | 0.00 | 6 | 5 | 8 |
| 18 | 9/26/16, a.m. | 31.0 | 4.37 | 4.37 | 4.39 | 4.38 | 4.34 | 0.04 | 6 | 5 | 8 |
| 19 | 10/25/16, p.m. | 32.0 | 4.53 | 4.55 | 4.59 | 4.56 | 4.50 | 0.06 | 13 | 5 | 8 |
| 20 | 10/26/16, a.m. | 33.0 | 5.47 | 5.45 | 5.49 | 5.47 | 5.39 | 0.08 | 13 | 5 | 8 |
| 21 | 11/27/16, p.m. | 32.0 | 5.70 | 5.69 | 5.77 | 5.72 | 5.75 | −0.03 | 13 | 16 | 8 |
| 22 | 11/28/16, a.m. | 33.5 | 4.87 | 4.82 | 4.87 | 4.85 | 4.82 | 0.03 | 13 | 16 | 8 |
| 23 | 12/26/16, p.m. | 32.0 | 5.34 | | 5.36 | 5.35 | 5.25 | 0.10 | 7 | | 8 |
| 24 | 12/27/16, a.m. | 32.0 | 5.33 | | 5.36 | 5.35 | 5.25 | 0.10 | 7 | | 8 |
| 25 | 1/24/17, p.m. | 31.0 | 5.01 | 5.00 | 5.03 | 5.01 | 4.92 | 0.09 | 13 | 7 | 8 |
| 26 | 1/25/17, p.m. | 31.5 | 4.82 | 4.85 | 4.84 | 4.84 | 4.73 | 0.11 | 9 | 3 | 8 |
| 27 | 3/11/17, p.m. | 30.5 | 4.93 | 4.95 | 4.98 | 4.95 | 4.85 | 0.10 | 4 | 14 | 8 |
| 28 | 3/12/17, a.m. | 32.0 | 5.10 | 5.12 | 5.12 | 5.11 | 5.02 | 0.09 | 4 | 14 | 8 |
| 29 | 3/26/17, p.m. | 31.0 | 5.47 | 5.46 | 5.48 | 5.47 | 5.40 | 0.07 | 7 | 13 | 8 |
| 30 | 3/28/17, a.m. | 30.5 | 4.70 | 4.71 | 4.70 | 4.70 | 4.61 | 0.09 | 7 | 13 | 8 |
| Average of 1 to 18 | | | | | 4.759 | 4.747 | 4.741 | 0.006 | | | |
| Average correction for calibration* | | | | | 0.048 | 0.047 | | 0.047 | | | |
| Average of 19 to 30 | | | | | 5.133 | 5.115 | 5.041 | 0.074 | | | |
| Average of all | | 31.4 | | | 4.937 | 4.923 | 4.861 | 0.062 | | | |

*Samples 1 to 18 were run in bottles calibrated with water. These were shown to give slightly lower results than with bottles calibrated with mercury.

TABLE B

*Jersey cow 268; age at freshening 2 years 4 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 6 Babcock readings by individuals | | | Average of all Babcock readings | Gravimetric method | | | | |
| | | | A | B | C | | | | A | B | C |
| 1 | 1/24/17, p.m. | 33.0 | 6.43 | 6.39 | 6.45 | 6.42 | 6.35 | 0.07 | 15 | 16 | 8 |
| 2 | 1/25/17, a.m. | 32.5 | 6.71 | 6.65 | 6.73 | 6.70 | 6.58 | 0.12 | 15 | 16 | 8 |
| 3 | 2/27/17, p.m. | 32.0 | 6.62 | 6.60 | 6.63 | 6.62 | 6.56 | 0.06 | 9 | 16 | 8 |
| 4 | 2/28/17, a.m. | 33.5 | 4.40 | 4.37 | 4.39 | 4.39 | 4.31 | 0.08 | 9 | 16 | 8 |
| 5 | 3/26/17, p.m. | 32.0 | 5.80 | 5.69 | 5.81 | 5.77 | 5.73 | 0.04 | 9 | 16 | 8 |
| 6 | 3/28/17, a.m. | 33.5 | 4.75 | 4.72 | 4.76 | 4.74 | 4.66 | 0.08 | 7 | 13 | 8 |
| 7 | 4/23/17, p.m. | 33.0 | 5.91 | 5.92 | 5.92 | 5.92 | 5.82 | 0.10 | 4 | 6 | 8 |
| 8 | 4/24/17, a.m. | 33.0 | 4.77 | 4.76 | 4.78 | 4.77 | 4.67 | 0.10 | 4 | 6 | 8 |
| 9 | 5/27/17, p.m. | 30.0 | 7.48 | 7.48 | 7.51 | 7.49 | 7.45 | 0.04 | 4 | 6 | 8 |
| 10 | 5/28/17, a.m. | 32.0 | 4.93 | 4.94 | 4.97 | 4.95 | 4.85 | 0.10 | 4 | 6 | 8 |
| 11 | 6/25/17, p.m. | 31.0 | 6.28 | 6.38 | 6.39 | 6.35 | 6.32 | 0.03 | 16 | 4 | 8 |
| 12 | 6/26/17, a.m. | 31.0 | 5.47 | 5.53 | 5.58 | 5.53 | 5.49 | 0.04 | 16 | 4 | 8 |
| 13 | 7/25/17, p.m. | 29.5 | 5.63 | | 5.63 | 5.63 | 5.52 | 0.11 | 7 | | 8 |
| 14 | 7/26/17, a.m. | 30.5 | 6.83 | | 6.83 | 6.83 | 6.69 | 0.14 | 7 | | 8 |
| 15 | 9/3/17, p.m. | 29.5 | 7.53 | 7.51 | 7.58 | 7.54 | 7.44 | 0.10 | 3 | 16 | 8 |
| 16 | 9/4/17, a.m. | 30.0 | 6.35 | 6.30 | 6.38 | 6.34 | 6.28 | 0.06 | 3 | 16 | 8 |
| 17 | 9/26/17, p.m. | 28.0 | 8.07 | 7.95 | 8.08 | 8.03 | 7.96 | 0.07 | 13 | 16 | 8 |
| 18 | 9/27/17, a.m. | 29.5 | 6.20 | 6.12 | 6.22 | 6.18 | 6.12 | 0.06 | 13 | 16 | 8 |
| 19 | 10/25/17, p.m. | 32.5 | 6.29 | 6.27 | 6.36 | 6.31 | 6.22 | 0.09 | 3 | 20 | 8 |
| 20 | 10/26/17, a.m. | | 6.97 | 6.93 | 6.98 | 6.96 | 6.88 | 0.08 | 3 | 20 | 8 |
| 21 | 12/11/17, p.m. | 33.5 | 7.93 | 7.91 | 8.01 | 7.95 | 7.89 | 0.06 | 22 | 21 | 8 |
| 22 | 12/12/17, a.m. | 34.0 | 6.78 | 6.80 | 6.82 | 6.80 | 6.71 | 0.09 | 22 | 21 | 8 |
| Average ..... | | 31.6 | | | 6.310 | 6.283 | 6.205 | 0.078 | | | |

TABLE C

*Guernsey cow 98; age at freshening 9 years, 4 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 6 Babcock readings by individuals | | | Average of all Babcock readings | Gravimetric method | | | | |
| | | | A | B | C | | | | A | B | C |
| 1 | 8/11/16, p.m. | 30.5 | 4.90 | | 4.93 | 4.92 | 4.86 | 0.06 | 4 | | 8 |
| 2 | 8/12/16, a.m. | 32.0 | 3.39 | | 3.46 | 3.43 | 3.37 | 0.06 | 4 | | 8 |
| 3 | 9/10/16, p.m. | 30.0 | 4.68 | 4.66 | 4.67 | 4.67 | 4.64 | 0.03 | 7 | 1 | 8 |
| 4 | 9/11/16, a.m. | 31.5 | 3.11 | 3.07 | 3.13 | 3.10 | 3.04 | 0.06 | 7 | 1 | 8 |
| 5 | 10/13/16, p.m. | 33.0 | 3.90 | 3.90 | 3.90 | 3.90 | 3.86 | 0.04 | 1 | 9 | 8 |
| 6 | 10/14/16, a.m. | 32.0 | 3.72 | 3.75 | 3.75 | 3.74 | 3.70 | 0.04 | 1 | 9 | 8 |
| 7 | 11/11/16, p.m. | 31.5 | 4.18 | 4.15 | 4.20 | 4.18 | 4.08 | 0.10 | 3 | 1 | 8 |
| 8 | 11/12/16, a.m. | 32.0 | 3.30 | 3.27 | 3.29 | 3.29 | 3.24 | 0.05 | 3 | 1 | 8 |
| 9 | 3/11/17, p.m. | 30.5 | 4.07 | 4.03 | 4.07 | 4.06 | 4.00 | 0.06 | 3 | 1 | 8 |
| 10 | 3/ 2/17, a.m. | 30.0 | 4.00 | 3.98 | 4.00 | 3.99 | 3.90 | 0.09 | 3 | 1 | 8 |
| 11 | 5/ 8/17, p.m. | 32.0 | 3.57 | 3.52 | 3.56 | 3.55 | 3.45 | 0.10 | 13 | 3 | 8 |
| 12 | 5/ 9/17, a.m. | 30.5 | 3.16 | 3.24 | 3.22 | 3.21 | 3.16 | 0.05 | 16 | 7 | 8 |
| 13 | 6/10/17, p.m. | 30.0 | 4.06 | 4.08 | 4.07 | 4.07 | 4.02 | 0.05 | 2 | 13 | 8 |
| 14 | 6/11/17, a.m. | 30.0 | 4.16 | 4.18 | 4.18 | 4.17 | 4.09 | 0.08 | 2 | 13 | 8 |
| 15 | 7/10/17, a.m. | 28.5 | 4.26 | | 4.25 | 4.26 | 4.20 | 0.06 | 1 | | 8 |
| 16 | 7/10/17, p.m. | 30.0 | 3.49 | 3.42 | 3.49 | 3.47 | 3.45 | 0.02 | 7 | 16 | 8 |
| 17 | 7/29/17, p.m. | 28.5 | 5.06 | 5.03 | 5.05 | 5.05 | 4.97 | 0.08 | 6 | 4 | 8 |
| 18 | 7/30/17, a.m. | 29.0 | 3.83 | 3.79 | 3.82 | 3.81 | 3.79 | 0.02 | 6 | 4 | 8 |
| 19 | 9/11/17, p.m. | 30.0 | 4.62 | | 4.61 | 4.62 | 4.58 | 0.04 | 13 | | 8 |
| 20 | 9/12/17, a.m. | 30.5 | 4.43 | | 4.44 | 4.44 | 4.39 | 0.05 | 13 | | 8 |
| 21 | 10/11/17, p.m. | 30.5 | 3.91 | 4.00 | 4.00 | 3.97 | 3.90 | 0.07 | 19 | 2 | 8 |
| 22 | 10/12/17, a.m. | 31.5 | 6.78 | 6.86 | 6.88 | 6.84 | 6.80 | 0.04 | 19 | 2 | 8 |
| Average..... | | 30.6 | | | 4.135 | 4.125 | 4.068 | 0.057 | | | |

TABLE D

*Guernsey cow 267; age at freshening 2 years, 2 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 6 Babcock readings by no. 8 10 per cent bottles | Average of 6 Babcock readings by individuals in 8 per cent bottles | | | Average of all Babcock readings 8 per cent bottles | Gravimetric method | | | | |
| | | | | A | B | C | | | | A | B | C |
| 1 | 11/13/16, p.m. | 33.5 | 5.10 | 5.03 | 5.06 | 5.06 | 5.05 | 4.97 | 0.08 | 7 | 14 | 8 |
| 2 | 11/14/16, a.m. | 35.0 | 3.98 | 3.80 | 3.81 | 3.87 | 3.83 | 3.74 | 0.09 | 7 | 14 | 8 |
| 3 | 12/11/16, p.m. | 32.0 | 5.83 | | 5.73 | 5.80 | 5.77 | 5.69 | 0.08 | | 16 | 8 |
| 4 | 12/12/16, a.m. | 33.0 | 4.81 | | 4.70 | 4.79 | 4.75 | 4.66 | 0.09 | | 16 | 8 |
| 5 | 1/10/17, p.m. | 33.0 | 5.71 | 5.63 | 5.70 | 5.71 | 5.68 | 5.57 | 0.11 | 6 | 4 | 8 |
| 6 | 1/11/17, a.m. | 34.0 | 4.54 | 4.43 | 4.40 | 4.47 | 4.43 | 4.32 | 0.11 | 6 | 4 | 8 |
| 7 | 2/14/17, p.m. | 33.0 | 5.59 | 5.56 | 5.56 | 5.57 | 5.56 | 5.44 | 0.12 | 15 | 2 | 8 |
| 8 | 2/15/17, a.m. | 34.0 | 4.21 | 4.20 | 4.16 | 4.18 | 4.18 | 4.07 | 0.11 | 15 | 2 | 8 |
| 9 | 3/11/17, p.m. | 31.0 | 6.73 | 6.78 | 6.78 | 6.78 | 6.78 | 6.64 | 0.14 | 6 | 2 | 8 |
| 10 | 3/12/17, a.m. | 34.0 | 4.00 | 3.99 | 3.98 | 4.00 | 3.99 | 3.91 | 0.08 | 6 | 2 | 8 |
| 11 | 5/ 8/17, p.m. | 33.0 | 5.23 | 5.30 | 5.23 | 5.30 | 5.28 | 5.16 | 0.12 | 13 | 3 | 8 |
| 12 | 5/ 9/17, a.m. | 33.0 | 5.51 | 5.42 | 5.49 | 5.49 | 5.47 | 5.39 | 0.08 | 16 | 7 | 8 |
| 13 | 6/10/17, p.m. | 31.0 | 6.63 | 6.56 | 6.61 | 6.62 | 6.60 | 6.49 | 0.11 | 16 | 18 | 8 |
| 14 | 6/11/17, a.m. | 31.0 | 4.60 | 4.50 | 4.59 | 4.57 | 4.55 | 4.44 | 0.11 | 16 | 18 | 8 |
| 15 | 7 9/17, p.m. | 31.0 | 4.93 | 4.90 | | 4.93 | 4.92 | 4.86 | 0.06 | 1 | | 8 |
| 16 | 7/10/17, a.m. | 30.5 | 4.64 | 4.60 | | 4.64 | 4.62 | 4.54 | 0.08 | 1 | | 8 |
| 17 | 7/29/17, p.m. | 28.5 | 5.30 | 5.34 | 5.25 | 5.29 | 5.29 | 5.20 | 0.09 | 13 | 1 | 8 |
| 18 | 7/30/17, a.m. | 30.0 | 6.50 | 6.41 | 6.38 | 6.42 | 6.40 | 6.35 | 0.05 | 6 | 4 | 8 |
| 19 | 9/11/17, p.m. | 32.0 | 4.86 | 4.89 | 4.88 | 4.89 | 4.89 | 4.80 | 0.09 | 2 | 6 | 8 |
| 20 | 9/12/17, a.m. | 30.5 | 5.46 | 5.47 | 5.42 | 5.48 | 5.46 | 5.39 | 0.07 | 2 | 6 | 8 |
| 21 | 10/11/17, p.m. | 33.0 | 5.42 | 5.32 | 5.41 | 5.40 | 5.38 | 5.28 | 0.10 | 19 | 2 | 8 |
| 22 | 10/12/17, a.m. | 32.0 | 5.84 | 5.76 | 5.85 | 5.87 | 5.83 | 5.72 | 0.11 | 19 | 2 | 8 |
| 23 | 11/11/17, p.m. | 30.5 | 5.62 | 5.55 | 5.50 | 5.58 | 5.54 | 5.51 | 0.03 | 4 | 1 | 8 |
| 24 | 11/12/17, a.m. | 34.0 | 5.03 | 4.98 | 4.96 | 4.98 | 4.97 | 4.91 | 0.06 | 4 | 1 | 8 |
| 25 | 12/11/17, p.m. | 32.5 | 6.69 | 6.61 | 6.63 | 6.67 | 6.64 | 6.56 | 0.08 | 22 | 21 | 8 |
| 26 | 12/12/17, a.m. | 34.0 | 5.98 | 5.88 | 5.90 | 5.94 | 5.91 | 5.80 | 0.11 | 22 | 21 | 8 |
| 27 | 1/15/18, p.m. | 32.5 | 6.08 | 6.09 | 6.05 | 6.09 | 6.08 | 6.00 | 0.08 | 2 | 22 | 8 |
| 28 | 1/16/18, a.m. | 34.0 | 6.13 | 6.02 | 5.98 | 6.08 | 6.03 | 5.93 | 0.10 | 22 | 19 | 8 |
| 29 | 2/10/18, p.m. | 35.5 | 5.92 | 5.82 | 5.88 | 5.88 | 5.86 | 5.80 | 0.06 | 19 | 21 | 8 |
| 30 | 2/12/18, a.m. | 33.5 | 6.08 | 5.93 | 5.98 | 6.01 | 5.97 | 5.90 | 0.07 | 19 | 21 | 8 |
| Average ..... | | 32.5 | 5.432 | | | 5.412 | 5.390 | 5.301 | 0.089 | | | |

TABLE E

*Ayrshire cow 230; age at freshening 4 years 3 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 6 Babcock readings by individuals | | | Average of all Babcock readings | Gravimetric method | | | | |
| | | | A | B | C | | | | A | B | C |
| 1 | 9/11/16, p.m. | 30.0 | 4.56 | | 4.52 | 4.54 | 4.44 | 0.10 | 4 | | 8 |
| 2 | 9/12/16, a.m. | 31.0 | 2.98 | | 3.00 | 2.99 | 2.90 | 0.09 | 4 | | 8 |
| 3 | 10/10/16, p.m. | 27.0 | 3.88 | 3.86 | 3.87 | 3.87 | 3.84 | 0.03 | 7 | 1 | 8 |
| 4 | 10/11/16, a.m. | 28.5 | 3.00 | 2.98 | 3.02 | 3.00 | 2.92 | 0.08 | 7 | 1 | 8 |
| 5 | 11/13/16, p.m. | 27.0 | 3.14 | 3.18 | 3.20 | 3.17 | 3.20 | 0.03 | 1 | 9 | 8 |
| 6 | 11/14/16, a.m. | 27.5 | 2.54 | 2.58 | 2.60 | 2.57 | 2.56 | 0.01 | 1 | 9 | 8 |
| 7 | 12/11/16, p.m. | 26.0 | 2.64 | 2.61 | 2.65 | 2.63 | 2.61 | 0.02 | 3 | 1 | 8 |
| 8 | 12/12/16, a.m. | 27.0 | 2.71 | 2.71 | 2.73 | 2.72 | 2.69 | 0.03 | 3 | 1 | 8 |
| 9 | 1/10/17, p.m. | 27.5 | 3.76 | 3.76 | 3.78 | 3.77 | 3.74 | 0.03 | 2 | 1 | 8 |
| 10 | 1/11/17, a.m. | 25.5 | 3.72 | 3.70 | 3.71 | 3.71 | 3.67 | 0.04 | 2 | 1 | 8 |
| 11 | 2/14/17, p.m. | 27.0 | 3.22 | 3.24 | 3.24 | 3.23 | 3.15 | 0.08 | 6 | 13 | 8 |
| 12 | 2/15/17, a.m. | 25.5 | 2.98 | 2.99 | 2.98 | 2.98 | 2.89 | 0.09 | 6 | 13 | 8 |
| 13 | 3/11/17, p.m. | 27.0 | 2.54 | 2.50 | 2.53 | 2.52 | 2.48 | 0.04 | 3 | 1 | 8 |
| 14 | 3/12/17, a.m. | 25.0 | 2.63 | 2.55 | 2.67 | 2.62 | 2.57 | 0.05 | 3 | 1 | 8 |
| Average..... | | 27.3 | | | 3.179 | 3.166 | 3.119 | 0.047 | | | |

TABLE F

*Ayrshire cow 243; age at freshening 2 years 8 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 6 Babcock readings by individuals | | | Average of all Babcock readings | Gravimetric method | | | | |
| | | | A | B | C | | | | A | B | C |
| 1 | 10/25/16, p.m. | 32.5 | 4.88 | 4.89 | 4.91 | 4.89 | 4.84 | 0.05 | 3 | 6 | 8 |
| 2 | 10/26/16, a.m. | 34.0 | 4.80 | 4.79 | 4.82 | 4.80 | 4.77 | 0.03 | 3 | 6 | 8 |
| 3 | 11/27/16, p.m. | 33.0 | 5.06 | 5.08 | 5.08 | 5.07 | 4.91 | 0.16 | 15 | 4 | 8 |
| 4 | 11/28/16, a.m. | 34.5 | 3.74 | 3.73 | 3.74 | 3.74 | 3.63 | 0.11 | 15 | 4 | 8 |
| 5 | 12/26/16, p.m. | 33.0 | 4.40 | 4.42 | 4.42 | 4.41 | 4.34 | 0.07 | 13 | 17 | 8 |
| 6 | 12/27/16, a.m. | 33.0 | 3.71 | 3.73 | 3.71 | 3.72 | 3.56 | 0.16 | 13 | 17 | 8 |
| 7 | 1/24/17, p.m. | 33.0 | 4.52 | 4.48 | 4.53 | 4.51 | 4.45 | 0.06 | 15 | 16 | 8 |
| 8 | 1/25/17, a.m. | 33.0 | 4.39 | 4.32 | 4.39 | 4.37 | 4.26 | 0.11 | 15 | 16 | 8 |
| 9 | 2/27/17, p.m. | 33.0 | 4.20 | 4.13 | 4.21 | 4.18 | 4.10 | 0.08 | 9 | 16 | 8 |
| 10 | 2/28/17, a.m. | 33.5 | 5.07 | 4.99 | 5.07 | 5.04 | 4.97 | 0.07 | 9 | 16 | 8 |
| 11 | 3/26/17 p.m. | 33.5 | 4.60 | 4.53 | 4.60 | 4.58 | 4.58 | 0.00 | 9 | 16 | 8 |
| 12 | 3/27/17, a.m. | 33.5 | 4.60 | 4.56 | 4.62 | 4.59 | 4.56 | 0.03 | 9 | 16 | 8 |
| 13 | 4/23/17, p.m. | 33.0 | 4.33 | | 4.35 | 4.34 | 4.33 | 0.01 | 9 | | 8 |
| 14 | 4/24/17, a.m. | 33.0 | 4.09 | | 4.10 | 4.10 | 4.08 | 0.02 | 9 | | 8 |
| 15 | 5/27/17, p.m. | 32.0 | 4.43 | 4.38 | 4.43 | 4.41 | 4.37 | 0.04 | 4 | 6 | 8 |
| 16 | 5/28/17, a.m. | 32.0 | 4.39 | 4.38 | 4.39 | 4.39 | 4.33 | 0.06 | 4 | 6 | 8 |
| 17 | 6/26/17, a.m. | 31.0 | 4.08 | 4.12 | 4.17 | 4.12 | 4.12 | 0.00 | 16 | 4 | 8 |
| 18 | 6/26/17, p.m. | 31.5 | 4.42 | | 4.43 | 4.43 | 4.39 | 0.04 | 7 | | 8 |
| 19 | 7/25/17, p.m. | 31.0 | 4.38 | | 4.37 | 4.38 | 4.34 | 0.04 | 7 | | 8 |
| 20 | 7/26/17, a.m. | 30.5 | 4.34 | 4.24 | 4.28 | 4.29 | 4.23 | 0.06 | 13 | 1 | 8 |
| 21 | 9/ 3/17, p.m. | 30.0 | 4.61 | 4.52 | 4.61 | 4.58 | 4.50 | 0.08 | 3 | 16 | 8 |
| 22 | 9/ 4/17, a.m. | 29.5 | 4.53 | 4.48 | 4.55 | 4.52 | 4.52 | 0.00 | 3 | 16 | 8 |
| 23 | 9/26/17, p.m. | 32.5 | 4.68 | 4.56 | 4.67 | 4.64 | 4.61 | 0.03 | 13 | 16 | 8 |
| 24 | 9/27/17, a.m. | 30.5 | 6.74 | 6.64 | 6.79 | 6.72 | 6.70 | 0.02 | 13 | 16 | 8 |
| 25 | 10/25/17, p.m. | 35.0 | 4.85 | 4.81 | 4.90 | 4.85 | 4.82 | 0.03 | 3 | 20 | 8 |
| 26 | 10/26/17, a.m. | 33.5 | 4.95 | | 5.01 | 4.98 | 5.00 | 0.02 | 19 | | 8 |
| Average ..... | | 32.5 | | | 4.583 | 4.563 | 4.512 | 0.052 | | | |

TABLE G

*Holstein cow 161; age at freshening 5 years 10 months*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 12 Babcock readings by individuals | | | Average of all Babcock readings | Gravimetric method | | | | |
| | | | A | B | C | | | | A | B | C |
| 1 | 3/26/16, p.m. | | 4.59 | 4.68 | 4.67 | 4.65 | 4.73 | −0.08 | 1 | 3 | 8 |
| 2 | 3/27/16, a.m. | | 3.88 | 3.80 | 3.88 | 3.85 | 3.88 | −0.03 | 9 | 10 | 8 |
| 3 | 3/27/16, m. | | 3.97 | | 3.98 | 3.98 | 3.98 | 0.00 | 9 | | 8 |
| 4 | 3/27/16, p.m. | | 4.54 | 4.56 | 4.56 | 4.55 | 4.50 | 0.05 | 11 | 12 | 8 |
| 5 | 4/26/16, a.m. | 32.0 | 3.47 | 3.40 | 3.48 | 3.45 | 3.40 | 0.05 | 9 | 6 | 8 |
| 6 | 4/26/16, m. | 32.0 | 3.21 | 3.17 | 3.21 | 3.20 | 3.17 | 0.03 | 3 | 10 | 8 |
| 7 | 4/26/16, p.m. | 32.5 | 3.88 | 3.96 | 3.91 | 3.92 | 3.87 | 0.05 | 5 | 12 | 8 |
| 8 | 4/27/16, a.m. | 33.0 | 3.52 | 3.51 | 3.53 | 3.52 | 3.48 | 0.04 | 4 | 7 | 8 |
| 9 | 5/27/16, p.m. | 32.0 | 3.76 | 3.80 | 3.81 | 3.79 | 3.83 | −0.04 | 1 | 9 | 8 |
| 10 | 5/29/16, a.m. | 32.5 | 2.72 | 2.73 | 2.75 | 2.73 | 2.73 | 0.00 | 3 | 5 | 8 |
| 11 | 6/26/16, p.m. | 31.5 | 3.30 | 3.26 | 3.32 | 3.29 | 3.34 | −0.05 | 7 | 5 | 8 |
| 12 | 6/27/16, a.m. | 32.5 | 2.06 | 2.07 | 2.09 | 2.07 | 2.12 | −0.05 | 2 | 7 | 8 |
| 13 | 7/25/16, p.m. | 30.0 | 3.31 | 3.30 | 3.32 | 3.31 | 3.32 | −0.01 | 4 | 7 | 8 |
| 14 | 7/26/16, a.m. | 31.0 | 2.70 | 2.71 | 2.70 | 2.70 | 2.61 | 0.09 | 9 | 12 | 8 |
| 15 | 8/ 3/16, p.m. | 32.0 | 2.90 | 2.87 | 2.90 | 2.89 | 2.87 | 0.02 | 9 | 7 | 8 |
| 16 | 8/ 4/16, a.m. | 31.5 | 2.81 | | 2.83 | 2.82 | 2.79 | 0.03 | 3 | | 8 |
| 17 | 8/25/16, p.m. | 32.0 | 2.18 | 2.19 | 2.19 | 2.19 | 2.19 | 0.00 | 3 | 9 | 8 |
| 18 | 8/26/16, a.m. | 31.0 | 3.20 | 3.22 | 3.21 | 3.21 | 3.21 | 0.00 | 3 | 9 | 8 |
| 19 | 9/25/16, p.m. | 31.5 | 3.63 | 3.59 | 3.63 | 3.62 | 3.58 | 0.04 | 3 | 6 | 8 |
| 20 | 9/26/16, a.m. | 31.0 | 3.27 | | 3.30 | 3.29 | 3.20 | 0.09 | 3 | | 8 |
| 21 | 11/27/16, p.m. | 33.5 | 3.62 | 3.58 | 3.61 | 3.60 | 3.61 | −0.01 | 4 | 6 | 8 |
| 22 | 11/28/16, a.m. | 31.5 | 3.21 | 3.19 | 3.22 | 3.21 | 3.18 | 0.03 | 4 | 6 | 8 |
| 23 | 12/26/16, p.m. | 32.5 | 3.62 | 3.60 | 3.61 | 3.61 | 3.61 | 0.00 | 2 | 9 | 8 |
| 24 | 12/27/16, a.m. | 32.0 | 2.95 | 2.93 | 2.95 | 2.94 | 2.91 | 0.03 | 2 | 9 | 8 |
| 25 | 1/24/17, p.m. | 33.0 | 3.80 | 3.80 | 3.79 | 3.80 | 3.79 | 0.01 | 13 | 7 | 8 |
| 26 | 1/25/17, p.m. | 31.5 | 1.97 | 1.97 | 2.00 | 1.98 | 1.97 | 0.01 | 9 | 3 | 8 |
| Average of 1 to 18 | | | | | | 3.352 | 3.340 | 3.334 | 0.006 | | | |
| Average correction for calibration | | | | | | 0.036 | 0.033 | | 0.033 | | | |
| Average of 19 to 26 | | | | | | 3.264 | 3.256 | 3.231 | 0.025 | | | |
| Average of all | | 31.9 | | | | 3.350 | 3.337 | 3.303 | 0.034 | | | |

TABLE H

*Holstein cow 269; age at freshening 2 years, 1 month*

| NUMBER | DATE | LACTOMETER READING | PER CENT FAT | | | | | | AVERAGE OF ALL BABCOCK READINGS ABOVE GRAVIMETRIC | INDIVIDUALS READING TESTS IN COLUMNS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average of 6 Babcock readings by no. 8 10 per cent bottles | Average of 6 Babcock readings by individuals in 8 per cent bottles | | | Average of all Babcock readings 8 per cent bottles | Gravimetric method | | | | |
| | | | | A | B | C | | | | A | B | C |
| 1 | 11/13/16, p.m. | 30.0 | 3.43 | 3.36 | 3.37 | 3.40 | 3.38 | 3.34 | 0.04 | 7 | 14 | 8 |
| 2 | 11/14/16, a.m. | 30.5 | 2.75 | 2.68 | 2.67 | 2.66 | 2.67 | 2.62 | 0.05 | 7 | 14 | 8 |
| 3 | 12/11/16, p.m. | 29.5 | 3.18 | | 3.12 | 3.18 | 3.15 | 3.09 | 0.06 | | 16 | 8 |
| 4 | 12/12/16, a.m. | 29.5 | 2.59 | | 2.50 | 2.57 | 2.54 | 2.47 | 0.07 | | 16 | 8 |
| 5 | 1/10/17, p.m. | 28.5 | 3.46 | 3.45 | 3.42 | 3.46 | 3.44 | 3.41 | 0.03 | 2 | 1 | 8 |
| 6 | 1/11/17, a.m. | 29.0 | 3.14 | 3.08 | 3.08 | 3.09 | 3.08 | 3.01 | 0.07 | 2 | 1 | 8 |
| 7 | 2/14/17, p.m. | 29.5 | 3.54 | 3.51 | 3.51 | 3.53 | 3.52 | 3.45 | 0.07 | 15 | 2 | 8 |
| 8 | 2/15/17, a.m. | 30.0 | 2.97 | 2.90 | 2.89 | 2.89 | 2.89 | 2.79 | 0.10 | 15 | 2 | 8 |
| 9 | 3/11/17, p.m. | 30.0 | 3.60 | 3.61 | 3.60 | 3.61 | 3.61 | 3.55 | 0.06 | 6 | 2 | 8 |
| 10 | 3/12/17, a.m. | 29.5 | 2.94 | 2.94 | 2.95 | 2.95 | 2.95 | 2.83 | 0.12 | 6 | 2 | 8 |
| 11 | 5/ 8/17, p.m. | 30.5 | 3.15 | 3.14 | 3.13 | 3.14 | 3.14 | 3.09 | 0.05 | 13 | 3 | 8 |
| 12 | 5/ 9/17, a.m. | 31.0 | 2.79 | 2.78 | 2.75 | 2.79 | 2.77 | 2.69 | 0.08 | 13 | 3 | 8 |
| 13 | 6/10/17, p.m. | 29.0 | 3.60 | 3.58 | 3.58 | 3.59 | 3.58 | 3.54 | 0.04 | 2 | 13 | 8 |
| 14 | 6/11/17, a.m. | 29.0 | 3.16 | 3.10 | 3.10 | 3.11 | 3.10 | 3.10 | 0.00 | 2 | 13 | 8 |
| 15 | 7/10/17, p.m. | 30.0 | 3.74 | 3.68 | 3.63 | 3.69 | 3.67 | 3.69 | −0.02 | 7 | 16 | 8 |
| 16 | 7/11/17, a.m. | 29.0 | 3.53 | 3.46 | 3.40 | 3.48 | 3.45 | 3.44 | 0.01 | 7 | 16 | 8 |
| 17 | 7/29/17, p.m. | 27.5 | 3.73 | 3.72 | 3.68 | 3.70 | 3.70 | 3.68 | 0.02 | 13 | 1 | 8 |
| 18 | 7/30/17, a.m. | 28.5 | 3.76 | 3.71 | 3.62 | 3.68 | 3.67 | 3.62 | 0.05 | 13 | 1 | 8 |
| 19 | 9/11/17, p.m. | 29.0 | 4.23 | 4.29 | 4.24 | 4.28 | 4.27 | 4.25 | 0.02 | 2 | 6 | 8 |
| 20 | 9/12/17, a.m. | 29.0 | 3.99 | 3.96 | 3.93 | 3.93 | 3.94 | 3.94 | 0.00 | 2 | 6 | 8 |
| Average ..... | | 29.4 | 3.364 | | | 3.337 | 3.326 | 3.280 | 0.046 | | | |

TABLE I

*Holstein cow 173; age at freshening 5 years 1 month*

| NUMBER | DATE | LACTOMETER READING | AVERAGE OF 6 BABCOCK READINGS BY NO. 8 | GRAVIMETRIC METHOD | AVERAGE OF BABCOCK READINGS ABOVE GRAVIMETRIC |
|---|---|---|---|---|---|
| 1 | 4/23/17, p.m. | 29.0 | 2.60 | 2.53 | 0.07 |
| 2 | 4/24/17, a.m. | 30.0 | 2.20 | 2.17 | 0.03 |
| 3 | 5/31/17, a.m. | 30.5 | 2.30 | 2.26 | 0.05 |
| 4 | 5/31/17, p.m. | 31.0 | 2.45 | 2.39 | 0.06 |
| 5 | 1/15/18, p.m. | 30.5 | 3.68 | 3.68 | 0.00 |
| 6 | 1/16/18, a.m. | 30.0 | 4.93 | 4.83 | 0.10 |
| 7 | 2/10/18, p.m. | 30.0 | 4.81 | 4.82 | −0.01 |
| 8 | 2/11/18, a.m. | | 4.08 | 4.02 | 0.06 |
| Average ..... | | 31.8 | 3.383 | 3.338 | 0.045 |

TABLE J

*Holstein cow 283; age at freshening 2 years*

| NUMBER | DATE | LACTOMETER READING | AVERAGE OF 6 BABCOCK READINGS BY NO. 8 | GRAVIMETRIC METHOD | AVERAGE OF BABCOCK READINGS ABOVE GRAVIMETRIC |
|---|---|---|---|---|---|
| 1 | 4/23/17, p.m. | 29.0 | 2.47 | 2.36 | 0.11 |
| 2 | 4/24/17, a.m. | 30.5 | 1.88 | 1.75 | 0.13 |
| 3 | 5/31/17, a.m. | 29.5 | 1.83 | 1.78 | 0.05 |
| 4 | 5/31/17, p.m. | 28.5 | 2.73 | 2.65 | 0.08 |
| 5 | 10/25/17, p.m. | | 3.19 | 3.10 | 0.09 |
| 6 | 10/26/17, a.m. | 27.0 | 5.93 | 5.84 | 0.09 |
| 7 | 12/12/17, a.m. | 32.0 | 2.75 | 2.71 | 0.04 |
| 8 | 12/12/17, p.m. | 29.5 | 2.81 | 2.71 | 0.10 |
| Average ..... | | 29.4 | 2.949 | 2.863 | 0.086 |

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# A STUDY OF THE ELECTRO-PURE PROCESS OF TREATING MILK

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## INTRODUCTION

The milk supply of Camp Meade is furnished by a private dairy company which has its plant for pasteurization and distribution located in the Camp. The plant obtains its supply of milk from the surrounding country and from dealers in Baltimore and after being brought to Camp is pasteurized before being distributed. Until last November the usual holding method of pasteurization was employed but about the middle of November the plant was destroyed by fire. When the new plant was built, instead of replacing the former equipment, the company installed the Electro-pure process which, as will be described later, makes use of a high voltage electric current for the purpose of purification. At the request of the Surgeon-General's Office this laboratory has made a rather thorough study of this process, the results of which are given in this report.

## THE ELECTRO-PURE PROCESS DESCRIBED

In figures 1 and 2 are shown two views of the Electro-pure machine. Figure 1 shows the machine with connections and figure 2 shows a close view of the machine itself. The milk to be treated is pumped from a storage vat through a pre-heater which is shown to the right in figure 1. Here the milk is heated by steam to a temperature of about 40°C. It is then delivered to the supply tank overhead. From this supply tank it enters the Electro-pure machine. After passing through the machine the milk enters the metal tank seen to the left in figure 1. This acts as a reservoir from which the hot milk is delivered to the cooler.

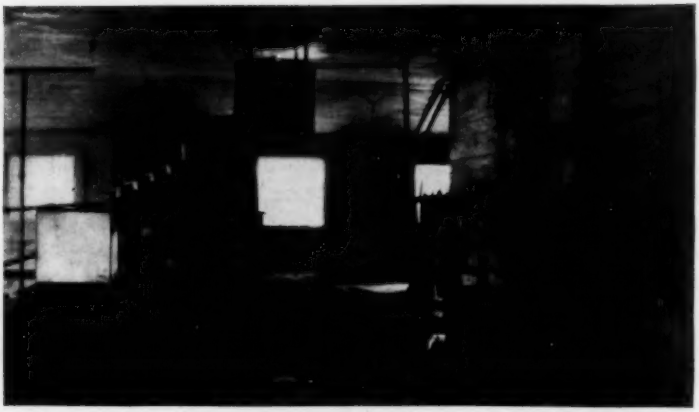

FIG. 1. SHOWING THE ELECTRO-PURE MACHINE WITH CONNECTIONS.

The pre-heater is seen to the right. The metal tank to the left acts as a reservoir which supplies the heated milk to the cooler.

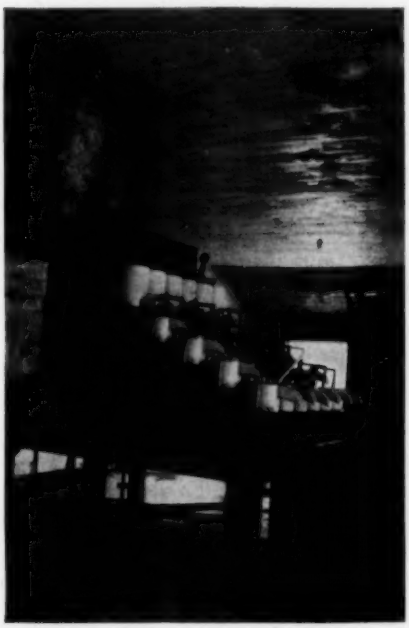

FIG. 2. CLOSE VIEW OF THE ELECTRO-PURE MACHINE

The Electro-pure machine itself is made up of several units, the number depending upon the capacity desired. Each unit is composed of a series of five porcelain cups arranged as in figure 2. Milk is supplied to each series of cups through a spigot leading from a box-shaped distributing tank. The first cup of each series has about twice the capacity of one of the remaining cups. The cups of a series are so arranged that milk entering the first cup will drain into the second cup which is placed slightly forward and below it. As this cup is filled it overflows into the third cup by means of a lip. In a like manner the stream of milk flows through all the cups of the series. In each of the smaller cups, which have a capacity of about 200 cc., is placed an electrode which is an insulated rod terminating in a copper disc. This disc is about the size of the inside of the cup and when in place is very near the bottom of the cup. Alternate electrodes are opposite. With the machine in operation the circuit is completed by the stream of milk. Due to the resistance the temperature of the milk is raised from about 40°C. entering the machine to about 70°C. leaving it. The current used is alternating and has a high voltage. With this particular machine the voltage is 2300, the amperage is 14 and the frequency is 25. A three phase system of wiring is used.

With the cost of current at 5 cents per kilowatt hour the cost of operating this machine is $2.74 per hour. This machine has 6 units and handles 5000 pounds of milk per hour. The cost per gallon for current amounts to 0.48 cent. The company owning the machine charges 0.5 cent per gallon royalty which brings the total cost of current plus royalty up to about 1 cent per gallon. It should be noted that this figure does not include the cost of heating the original milk up to 40°C.

## REVIEW OF LITERATURE

Search of the literature bearing on the subject of electrical treatment of milk revealed it to be scarce. A few articles bearing on the subject are briefly reviewed here.

Jackson and Rothera (1), 1914, investigated "Milk, Its Sugar,

Conductivity and Depression of the Freezing Point." They concluded that the electrical conductivity of milk, which is mainly due to the soluble salts, is inversely proportional to the lactose content. The caseinogen mechanically obstructs the carriage of electricity by the moving ions, so that 1 per cent protein depresses conductivity by 2.5 per cent. Reference is made to Petersen, 1914, "who finds no proportionality between specific gravity and electrical resistance or total solids and resistance, but mentions a general proportionality to the ash though there is no direct relationship."

Stone (2), 1909, studied the "Influence of Electricity on Microorganisms." The following results are quoted from the Experiment Station Record, although the original paper has also been consulted.

> The studies with water were taken up primarily to determine the possibility of obtaining pure water by means of electricity, but it was soon found that instead of a decrease in the bacterial content there was an increase from the electrical stimulation. This was found to be quite constant where the strength of the current was not too great.
>
> Similar results were obtained with milk, and where static electricity was used a positive charge was found to favor the development of bacteria to a very considerable extent. Where heavy charges were used the number of organisms decreased very decidedly, but feeble electrical currents and small static charges acted as stimuli to bacteria in milk, increasing their number perceptibly. . . . .
>
> As a result of all experiments in the growing of plants, it was found that when currents of 0.1 to 0.6 milliamperes were used all forms of plant life were stimulated.

Beattie (3), 1914, investigated "Electrical Treatment of Milk for Infant Feeding." The apparatus he worked with was different from the Electro-pure process used in this work. It allowed a stream of milk to run through a glass tube at the experimental rate of 6.75 gallons per hour, and later at the rate of 30 gallons per hour in a large scale plant at Liverpool. He successfully used a rapidly alternating current of 3600 to 4200 volts, and 2 to 2.3 amperes. The maximum temperatures developed

in the milk ranged from 60 to 64°C. He made 140 separate daily tests and says in part:

> Thus it will be seen that milk was only in rare instance absolutely sterile, but that it was free from dangerous or disease-producing bacteria and from the milk-souring bacteria and that there was an enormous reduction in the number of all other forms of bacterial life. The actual reduction was over 99 per cent.
>
> The chemical composition is unaltered (so far as chemical analysis can ascertain); chemist's reports also give evidence of non-increase of acidity (which of course is due to the destruction of acid-producing bacteria) and increased keeping quality of milk. Mr. Roberts, City Analyst, also states that the lactalbumin which is coagulated in ordinary sterilized milk, is not coagulated in the electrically treated milk. In addition the enzymes are not destroyed.
>
> Each unit quantity of milk is exposed to the temperature noted on the table for such a brief period—several seconds—that heating effects, we believe, can be neglected.
>
> The milk after treatment is, in my opinion, perfectly satisfactory as food for infants.

Zilva (4), 1914, investigated "The Rate of Inactivation by Heat of Peroxidase in Milk." He found that "91.2 per cent of the original peroxidase would remain after heating the milk for three minutes at 158°F. (70°C.)." Also that "four hours at 65°C. makes hardly any perceptible difference to the peroxidase content of milk," but that "at temperatures beyond 71°C. very short periods of heating produce well marked impressions on the peroxidase content of milk."

## PURPOSE OF THE INVESTIGATION

The investigation here reported was conducted with the following points in view:

1. To determine the efficiency of the Electro-pure process in destroying bacteria together with the keeping quality of the milk so treated.
2. To determine whether the bactericidal action of the proc-

ess is a result of the current alone, the heat produced by the current or by a combination of these two factors.

3. To study the chemical changes, if any, which are produced by the treatment.

4. To study the effect of the process on some of the enzymes in milk, the time required for coagulation with rennin, the cream line, acidity etc.

5. To determine if there is any change in nutritive value, such as the destruction of the so-called "vitamines."

## EXPERIMENTAL WORK

### *1. Bacteriological tests—methods, results, discussion*

In carrying on the bacteriological tests in this work the standard methods of the American Public Health Association were followed. Culture media used were; nutrient agar, 1 per cent lactose broth in Dunham's fermentation tubes and Endo's medium. The lactose broth tubes were inoculated with 0.1, 0.01 and 0.001 cc. of the given sample of milk at the same time that the platings were made. They were then incubated at 37°C. and examined for gas production after twenty-four and forty-eight hours. Tubes showing at least 10 per cent gas had transfers made to Endo's plates which were later examined for typical colonies of B. coli.

*a. Destruction of bacteria.* To start with, it was of interest to determine just what reduction in the bacterial content of raw milk the Electro-pure machine could bring about. In this connection four samples of good raw milk, (i.e., raw milk with a low bacteria count) warmed in the pre-heater to 32 to 40°C. were taken at intervals as it entered the Electro-pure machine. Four corresponding samples of electro-treated milk leaving the machine were taken at the same time. The samples were carefully collected, immediately cooled by agitation in running water, placed on ice in the laboratory and analyzed within two hours after being collected. Three agar plates were prepared from each sample.

This experiment was repeated on four days and the results obtained are given in table 1, experiment 1.

A test similar to the above was made under the same conditions but poor raw milk (i.e., milk with a high bacteria count) was used. The results obtained are given in table 1, experiment 2.

As shown in table 1, sixteen samples of good quality of raw milk had an average bacteria count of 161,500 per cubic centimeter and twelve of these contained in 0.1 cc. of milk organisms capable of producing gas from lactose and giving a reaction positive for B. coli on Endo's medium.

The corresponding samples of milk treated by the Electro-pure process had an average bacteria count of 2100 per cubic centimeter (thus corresponding in final count to grade A pasteurized milk according to the New York City standard) or an average reduction of 98.7 per cent and containing organisms capable of producing gas from lactose and giving a reaction positive for B. coli on Endo's medium in only two out of sixteen samples that were analyzed.

Sixteen samples of poor quality of raw milk had an average bacteria count of 2,588,000 per cubic centimeter and all samples but two contained in 0.001 cc. of milk organisms capable of producing gas from lactose and giving a reaction positive for B. coli on Endo's medium. The corresponding samples of milk treated by the Electro-pure process had an average bacteria count of 33,700 per cubic centimeter (thus corresponding in final count to grade B. pasteurized milk according to the New York City standard) or an average reduction of 98.7 per cent and containing organisms capable of producing gas from lactose only in one sample out of sixteen that were analyzed.

These results compare favorably with those obtained in Ottawa (7) where pasteurized milk for the year ending October 31, 1915, showed 45 per cent of all samples analyzed with a bacterial count under 10,000 per cubic centimeter and 50.4 per cent of all samples analyzed with a bacterial count from 10,000 to 50,000 per cubic centimeter. The average bacterial count per cubic centimeter of all pasteurized samples for the same year was

TABLE 1

*Destruction of bacteria in milk treated by the electro-pure process*

| RAW MILK ENTERING THE MACHINE | | | | | ELECTRO-TREATED MILK LEAVING THE MACHINE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample number | Temperature | Total bacteria count per cubic centimeter, 48 hours at 37°C. | Gas in lactose broth 0.1 cc. 0.01 cc. 0.001 cc. | Endo's reaction | Sample number | Temperature | Total bacteria count per cubic centimeter, 48 hours at 37°C. | Gas in lactose broth 0.1 cc. 0.01 cc. 0.001 cc. | Endo's reaction |
| **Experiment 1, with good quality raw milk—four days' run** | | | | | | | | | |
| | *deg. C.* | | | | | *deg. C.* | | | |
| 1 | 35 | 150,000 | − − − | | 1 | 75 | 3,000 | − − − | |
| 2 | 35 | 250,000 | − − − | | 2 | 75 | 200 | − − − | |
| 3 | 38 | 100,000 | − − − | | 3 | 75 | 1,000 | − − − | |
| 4 | 38 | 110,000 | − − − | | 4 | 75 | 100 | − − − | |
| 5 | 40 | 135,000 | + − − | + | 5 | 77 | 1,300 | − − − | |
| 6 | 40 | 50,000 | + − − | + | 6 | 77 | 500 | − − − | |
| 7 | 38 | 170,000 | + + + | + | 7 | 72 | 500 | − − − | |
| 8 | 38 | 140,000 | + + + | + | 8 | 72 | 500 | − − − | |
| 9 | 40 | 175,000 | + + + | + | 9 | 74 | 1,800 | − − − | |
| 10 | 40 | 300,000 | + + + | + | 10 | 74 | 1,700 | + − − | + |
| 11 | 40 | 250,000 | + + − | + | 11 | 72 | 6,500 | − − − | |
| 12 | 40 | 250,000 | + + + | + | 12 | 72 | 3,500 | − − − | |
| 13 | 32–40 | 150,000 | + + + | + | 13 | 73 | 800 | − − − | |
| 14 | 32–40 | 140,000 | + + − | + | 14 | 73 | 500 | − − − | |
| 15 | 32–40 | 65,000 | + + + | + | 15 | 68 | − | − − − | |
| 16 | 32–40 | 150,000 | + + − | + | 16 | 68 | 12,000 | − + + | + |
| Average of sixteen samples, 161,500 | | | | | Average of sixteen samples, 2,100<br>Average per cent reduction, 98.7 | | | | |
| **Experiment 2, with poor quality raw milk—four days' run** | | | | | | | | | |
| 1 | 40 | 12,000,000 | + + + | + | 1 | 74 | 11,000 | − − − | |
| 2 | 40 | 10,000,000 | + + + | + | 2 | 74 | 15,000 | − − − | |
| 3 | 38 | 3,000,000 | + + + | + | 3 | 68 | 70,000 | − − − | |
| 4 | 38 | 2,500,000 | + + + | + | 4 | 68 | 80,000 | − − − | |
| 5 | 38 | 1,100,000 | + + + | + | 5 | 75 | 115,000 | + − − | No growth |
| 6 | 38 | 4,500,000 | + + + | + | 6 | 75 | 135,000 | − − − | |
| 7 | 40 | 600,000 | + − − | − | 7 | 70 | 11,000 | − − − | |
| 8 | 40 | 350,000 | + − − | No growth | 8 | 70 | 11,500 | − − − | |
| 9 | 38 | 550,000 | + + + | + | 9 | 70 | 11,000 | − − − | |
| 10 | 38 | 600,000 | + + + | + | 10 | 70 | 15,000 | − − − | |
| 11 | 38 | 1,000,000 | + + + | + | 11 | 70 | 12,500 | − − − | |
| 12 | 38 | 1,000,000 | + + + | + | 12 | 70 | 18,000 | − − − | |
| 13 | 2 | 1,400,000 | + + + | + | 13 | 76 | 5,200 | − − − | |
| 14 | − | 1,200,000 | + + + | + | 14 | 74 | 14,000 | − − − | |
| 15 | − | 600,000 | + + + | + | 15 | 74 | 10,000 | − − − | |
| 16 | − | 1,000,000 | + + + | + | 16 | 74 | 5,500 | − − − | |
| Average of sixteen samples, 2,588,000 | | | | | Average of sixteen samples, 33,700<br>Average per cent reduction, 98.7 | | | | |

shown to be 19,600 per cubic centimeter and the average B. coli 102 per cubic centimeter.

Results reported in table 1 seem to show that the Electro-pure machine operated under the conditions indicated in these experiments gives a very satisfactory reduction of the total count in good raw milk, a satisfactory reduction in poor raw milk and at the same time effectively destroys nearly all lactose fermenting, Endo positive organisms in raw milk.

*b. Study of milk issuing from the different units in the Electro-pure process.* It was the intention in planning this test to obtain some information as to how the bacteria counts compared from the various units or series of cups. In other words to determine whether there was uniformity or variation in bacteria counts of the treated milk at the moment it left the Electro-pure machine.

Strength of the electric current and rate of milk flow remained unchanged throughout this test. The temperature of raw milk entering the machine was 40°C. and the temperature of treated milk leaving the machine was 71°C. in every instance. A sample of raw milk was taken and immediately after that duplicate samples of corresponding treated milk from two units. The five samples collected in this way were rapidly cooled by immersing and agitating in running cold water. After an interval the next five samples were collected in the same way, and later the last five samples, making in all three raw samples, and two samples from each of the six units. This test was repeated after several days and the results obtained are indicated in table 2.

Table 2 shows the lowest total bacteria counts to be about 1000 per cubic centimeter and the highest counts to be about 40,000 per cubic centimeter. Out of twelve tests in this experiment only four tests averaged above 10,000 per cubic centimeter. Lactose fermenting organisms appeared in 1 cc. portions only in four out of twenty four of the treated milk, but they failed to grow on Endo's medium.

All of the samples tested in this experiment correspond in final bacterial count to grade B pasteurized milk, and a large

TABLE 2

*Study of milk issuing from the different units in the electro-pure process*

| | RAW MILK | TREATED MILK FROM UNIT | | | | RAW MILK | TREATED MILK FROM UNIT | | | | RAW MILK | TREATED MILK FROM UNIT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1 | 2 | 2 | | 3 | 3 | 4 | 4 | | 5 | 5 | 6 | 6 |
| **Experiment 1** | | | | | | | | | | | | | | | |
| Thousand bacteria per cubic centimeter, 48 hours at 37°C. | 1,250 | 40 | 42.5 | 7 | 14 | 1,400 | 25 | 18.5 | 6 | 1 | 240 | 1.7 | 12.5 | 1.5 | 1 |
| Gas in lactose broth: 0.1 cc. | 0.1 cc. | | | | | 0.1 cc. | | | | | 0.1 cc. | | | | |
| Gas in lactose broth: 0.01 cc. | 0.01 cc. | 1 cc. | – | – | – | 0.01 cc. | – | – | – | 1 cc. | 0.01 cc. | – | – | – | – |
| Gas in lactose broth: 0.001 cc. | 0.001 cc. | | | | | 0.001 cc. | | | | | 0.001 cc. | | | | |
| Endo's reaction | + | | * | – | – | + | – | – | – | * | + | – | – | – | – |
| Average count | 26,000 | | | | | 12,500 | | | | | 4,000 | | | | |
| Bacteria destroyed | 97.2 per cent | | | | | 98.75 per cent | | | | | 98 per cent | | | | |
| **Experiment 2** | | | | | | | | | | | | | | | |
| Thousand bacteria per cubic centimeter, 48 hours at 37°C. | 110 | 2.7 | 1.5 | 2 | 4 | 145 | 3.3 | 1 | 4 | 5 | 200 | 7 | 23 | 19 | 20 |
| Gas in lactose broth: 0.1 cc. | 0.1 cc. | | | | | 0.1 cc. | | | | | 0.1 cc. | | | | |
| Gas in lactose broth: 0.01 cc. | 0.01 cc. | – | – | – | – | 0.01 cc. | – | 1 cc. | – | – | 0.01 cc. | – | – | 1 cc. | – |
| Gas in lactose broth: 0.001 cc. | 0.001 cc. | | | | | 0.001 cc. | | | | | 0.001 cc. | | | | |
| Endo's reaction | + | – | – | – | – | + | – | * | – | – | + | – | – | * | – |
| Average count | 2,500 | | | | | 3,400 | | | | | 17,250 | | | | |
| Bacteria destroyed | 97.6 per cent | | | | | 96.5 per cent | | | | | 89.5 per cent | | | | |

* No growth.

portion of them correspond to grade A pasteurized milk according to the standard of the New York City Board of Health.

While it cannot be said that the milk issuing from the different units in the Electro-pure process is absolutely uniform as regards bacteria counts, the fluctuations in these counts are not unreasonable and some of them are within the limits of experimental error.

*c. Keeping quality of Electro-pure milk at low temperatures.* Seven pint bottles were cleaned with extra care, thoroughly steamed and allowed to cool. These were then mechanically filled and capped in the "Milwaukee" filler, the milk used having just been processed by the Electro-pure method and cooled.

One of the samples was analyzed immediately. The remaining ones were stored in a refrigerator in which the temperature was not constant. One bottle of milk was taken out daily and tested in duplicate, three agar plates being made of each sample. This test lasted a week and was recorded in table 3, experiment 1.

When the above test was completed, it was decided to repeat it and to run it for a longer period. This time twelve pint bottles were put up. The test was discontinued when the milk spoiled on the tenth day. The results of this test are given in table 3, experiment 2.

Table 3, experiment 1, showed in freshly treated milk an initial count of 2000 bacteria per cubic centimeter which increased to 150,000 bacteria per cubic centimeter on the third day probably as a result of slow growth at 11°C. and fell to 10,000 bacteria per cubic centimeter on the sixth day. There also was a very slight decrease in acidity. The odor and taste of milk did not change. No lactose fermenting organisms appeared in the freshly treated milk in 0.1, 0.01 and 0.001 cc. quantities used, and none appeared in the same quantities of milk during the six days of storage in the refrigerator.

Table 3, experiment 2, showed in freshly treated milk an initial count of 300 bacteria per cubic centimeter which increased to 40,000 on the sixth day and to 2,500,000 on the eighth day. On the fifth day there was a slight decrease in acidity and evidence of lactose fermenting, Endo positive organisms. The milk

TABLE 3

*Keeping quality of electro-pure milk at low temperatures*

Experiment 1

| | SOURCE OF SAMPLE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Taken from the process | 1 day | 2 days | 3 days | 4 days | 5 days | 6 days |
| Temperature in refrigerator | | 10°C. | 11°C. | 5°C. | 0°C. | 0°C. | 10°C. |
| Bacteria count per cubic centimeter, 48 hours at 37°C. | 2,000 | 2,000 | 3,500 | 150,000 | 50,000 | 4,700 | 10,000 |
| | 1,700 | 5,000 | 5,000 | 160,000 | 80,000 | 5,000 | 11,000 |
| Per cent acidity calculated as lactic | 0.25 | 0.26 | 0.26 | 0.24 | 0.23 | 0.23 | 0.23 |
| Fermentation | No change evident to taste or smell | | | | | | |
| Gas in lactose broth | No gas in 0.1, 0.01, or 0.001 cc. of treated milk | | | | | | |

Experiment 2

| | SOURCE OF SAMPLE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Taken from the process | 1 day | 2 days | 3 days | 4 days | 5 days | 6 days | 7 days | 8 days | 9 days |
| Temperature in refrigerator | | | 6°C. | 5°C. | 9°C. | 11°C. | 7°C. | 8°C. | 10°C. | 8°C. |
| Bacteria count per cubic centimeter 48 hours, at 37°C. | 300 | 300 | 1,000 | 400 | 3,000 | 1,000 | 40,000 | 30,000 | 2,500,000 | 1,400,000 |
| | 500 | 500 | 1,000 | 500 | 2,000 | 1,000 | 42,000 | 35,000 | 2,000,000 | 2,000,000 |
| Per cent acidity calculated as lactic | 0.23 | 0.23 | 0.23 | 0.24 | 0.24 | 0.21 | 0.21 | 0.20 | 0.20 | 0.22 |
| Fermentation | No change evident to taste or smell | | | | | | | | Bad smell | Bad smell |
| Gas in lactose broth (cc.) | No gas in 0.1, 0.01, or 0.001 cc. of treated milk | | | | | 0.1, 0.01 | 0.01 | 0.1, 0.01 | 0.1, 0.01 | 0.1, 0.001 |
| Endo's reaction | | | | | | + | + | + | + | |

developed a bad odor on the eighth day and was unfit for drinking on the tenth day.

In view of the above it appears that milk treated by the Electro-pure process has good keeping qualities for about five days at 5 to 10°C. which is likely to be found in commercial plants.

*d. Heat vs. electric current.* While studying the Electro-pure process it became apparent that two factors were involved, heat and electric current. Questions, such as the following, at once presented themselves; can the electric current itself, regardless of temperature, bring about a satisfactory reduction of bacteria in milk; can the heat alone, regardless of the electric current, produce the same results? To answer these questions the tests that follow were undertaken.

The first test, recorded in table 4, was made in order to study the effect of temperature in the Electro-pure process on the bacteria count in the treated milk. The strength of the electric current and the rate of milk flow remained unchanged throughout this experiment. The temperature of the milk entering the Electro-pure machine was adjusted in the pre-heater so as to give any desired temperature to the treated milk leaving the Electro-pure machine. In this way it was possible to obtain for bacteriological analysis samples of Electro-pure milk which had been heated to about 75, 70, 65, 60 and 55°C. in going through the machine. At the same time samples of raw milk entering the machine were also taken. This test was repeated on three days.

The results obtained are easily followed in table 4, experiments 1, 2 and 3. It seems that, with the electric current of a constant strength, the total bacteria counts in electro-treated milk rise with the fall in the temperature of the treated milk leaving the machine; that the percentage of bacteria destroyed in the process falls with the fall in this temperature, and that the lactose fermenting, Endo positive organisms, when present in raw milk, are more effectively destroyed in this process at higher temperatures.

In table 4 it should be noted that the percentage reduction of bacteria is based on the average of the four raw samples in each

TABLE 4

*Effect of temperatures in the electro-pure process on the bacteria count in the treated milk—three days' run*

| KIND OF SAMPLE | TEMPERATURE | BACTERIA COUNT PER CUBIC CENTIMETER, 48 HOURS AT 37°C. | GAS IN LACTOSE BROTH IN | | | ENDO'S REACTION | PER CENT OF BACTERIA DESTROYED BASED ON AVERAGE R |
|---|---|---|---|---|---|---|---|
| | | | 0.1 cc. | 0.01 cc. | 0.001 cc. | | |
| | | **Experiment 1*** | | | | | |
| | *deg. C.* | | | | | | |
| R† | – | 150,000 | + | + | + | + | |
| T‡ | 73 | 800 | – | – | – | – | 99.5 |
| T | 73 | 500 | – | – | – | – | |
| R | – | 140,000 | + | + | + | + | |
| T | 68 | – | + | – | – | + | 90.5 |
| T | 68 | 12,000 | | + | + | + | |
| R | – | 65,000 | + | + | + | + | |
| T | 60 | 40,000 | + | + | – | + | 80.0 |
| T | 60 | 12,000 | – | – | – | – | |
| R | – | 150,000 | + | + | – | + | |
| T | 55 | 40,000 | + | + | + | + | 60.0 |
| T | 55 | 60,000 | + | – | – | + | |
| R Average..... | | 126,000 | | | | | |
| | | **Experiment 2** | | | | | |
| R | 38 | 600,000 | + | + | + | + | |
| T | 71 | 24,000 | + | – | + | § | 95.3 |
| T | 71 | 23,000 | – | – | – | – | |
| R | 34 | 580,000 | + | + | – | + | |
| T | 65 | 50,000 | – | – | – | – | 88.0 |
| T | 65 | 70,000 | – | – | – | – | |
| R | 29 | 360,000 | – | + | – | + | |
| T | 59 | 260,000 | – | – | – | – | 65.0 |
| T | 59 | 90,000 | – | – | – | – | |
| R | 25 | 450,000 | – | – | – | – | |
| T | 55 | 500,000 | – | – | – | – | 2.0 |
| T | 55 | 480,000 | – | – | – | – | |
| R Average..... | | 498,000 | | | | | |

TABLE 4—*Concluded*

| KIND OF SAMPLE | TEMPERATURE | BACTERIA COUNT PER CUBIC CENTIMETER, 48 HOURS AT 37°C. | GAS IN LACTOSE BROTH IN | | | ENDO'S REACTION | PER CENT OF BACTERIA DESTROYED BASED ON AVERAGE R |
|---|---|---|---|---|---|---|---|
| | | | 0.1 cc. | 0.01 cc. | 0.001 cc. | | |
| Experiment 3 | | | | | | | |
| | *deg. C.* | | | | | | |
| R | 38 | 650,000 | + | + | + | + | |
| T. | 69 | 50,000 | − | − | − | − | 89.0 |
| T | 69 | 50,000 | − | − | − | − | |
| R | 35 | 400,000 | − | + | + | + | |
| T | 64 | 60,000 | − | − | − | − | 85.0 |
| T | 64 | 75,000 | − | − | − | − | |
| R | 32 | 650,000 | + | + | + | + | |
| T | 60 | 40,000 | − | − | − | − | 80.0 |
| T | 60 | 140,000 | − | − | − | − | |
| R | 30 | 120,000 | + | + | + | + | |
| T | 55 | 260,000 | − | − | − | − | 50.0 |
| T | 55 | 200,000 | + | + | + | + | |
| R Average..... | | 455,000 | | | | | |

* R in experiment 1 had the temperature varying between 32 and 40°C.
† R refers to raw milk entering the machine.
‡ T refers to the treated milk leaving the machine.
§ No growth.

experiment. It was felt that this average would represent more truly the conditions and would also account for the increase in bacteria count of treated milk at 55°C. in experiments 2 and 3. However these increases might be accounted for by a breaking up of colonies of bacteria in passing through the machine. At any rate it should be noted that in experiments 2 and 3 there is no reduction of bacteria at 55°C. if calculations are based on the sample of raw milk taken just prior to sampling the treated milk.

The obvious conclusion from the above is that the electric current itself, as used in this test, does not bring about satisfactory reduction of bacteria in milk.

The second test, recorded in table 5, was made in order to compare results obtained by the Electro-pure process and milk

"flashed" at the dairy through a heater of the type known as the "Reid's flash pasteurizer." In this work samples of raw milk were secured after thorough mixing in the receiving vat. The electro treated milk was collected as usual at the moment it left the Electro-pure machine, and some was collected from the "Milwaukee" filler after the milk had been cooled. The "flashed" milk was heated by means of hot water to 65, 70, 75, and 80°C. and samples were collected of "flashed" milk as it left the heater, as it entered the Electro-pure machine and as it left the Electro-pure machine. It must be noted in this connection that the electric current was shut off while the "flashing" experiment was conducted, so that the reduction in bacteria count, if any, would be due solely to the effect of heat.

The results obtained are indicated in table 5, experiment 1 and 2. The electro treated milk from the machine did as well as in the previous tests but a curious thing was observed in the same lot of electro treated milk obtained from the filler. A very evident reduction had taken place. This was accounted for by the fact that when treated milk left the machine at 70°C. it was exposed at that temperature in the tank for a brief period just before it passed by gravity to the cooler. A distinct reduction was noted in "flashed" milk, particularly at a temperature of 70°C. or higher. Milk "flashed" to 70°C. apparently gave even better results, so far as total bacteria count was concerned, than the electro treated milk at 74°C. in experiment 1, or electro treated milk at 70°C. in experiment 2. But here the question of time should be considered. It is apparent that milk spent more time in the "flash" pasteurizer at any given temperature than in the Electro-pure machine at the same temperature. It was therefore decided to determine the time factor in the Electro-pure machine and to reproduce it in the case of heating by the "flash" method. With this in mind the next test was undertaken.

One series of four cups was filled with water till overflowing ceased. Then a strong solution of potassium permanganate was added to the highest cup in the series, and water from the feed tank was allowed to flow into the above series of cups until

the color of the potassium permanganate was no longer visible in the lowest cup. Observations with stop watches were made and the average of ten consecutive tests indicated that the first traces of color left the last cup in five seconds, and that the last traces of color left the last cup in thirty-four seconds. It seems, then, that the time milk spent in going through the machine was between five and thirty-four seconds or an average of about twenty seconds. This test was carried out without the electric current.

It required, in the above test, an average of 2500 cc. of water to flush out in thirty-four seconds the color of potassium permanganate from the series of four cups. In other words the water was running through the machine at the rate of 74 cc. per second. This compares in a general way with the results obtained in the actual operation of the Electro-pure machine while the milk was treated and timed. The rate was found to be 5000 pounds of milk per hour, which reduces to 105 cc. per second.

Next it became necessary to set up an apparatus that would "flash" the milk up to 70°C. in ten seconds or in twenty seconds in order to duplicate, if possible, the condition of time as found in the Electro-pure process. It was found after some preliminary experimentation that a water bath at 82°C. would "flash" 5 cc. of milk in a 250 cc. Fry's Erlenmeyer flask from an initial temperature of 40°C. up to 70°C. in ten seconds, and that a water bath at 75°C. would under similar conditions "flash" it up to 70°C. in twenty seconds.

The third test, recorded in table 6, was made for the sake of comparing milk treated by the Electro-pure process and milk "flashed" in the laboratory in the length of time approximately spent by milk in the Electro-pure process and at the same temperature.

The electro treated and the raw milk samples were collected at the dairy in the usual way. Enough raw milk was obtained for "flashing" work in the laboratory. Here it was warmed up to 40°C., 5 cc. portion of a representative sample was transferred with a sterile pipette to a sterile 250 cc. Fry's Erlenmeyer

flask which had been kept in the water bath at 82°C. By agitating the flask in the water bath the milk was "flashed" up to 70°C. in ten seconds. The milk was then cooled at once in a cold water bath. The next 5 cc. portions of milk were flashed to the desired temperature in the desired length of time and then transferred to a water bath at 70°C. and held for ten seconds, twenty seconds, etc., as indicated in table 6, experiment 1, after which they were rapidly cooled. The same method was followed in experiment 2, except that the temperature of the "flashing" bath was 75°C. which made it possible to heat the raw milk in twenty seconds from the initial temperature of 40°C. to that of 70°C.

The results obtained show satisfactory reduction in number of bacteria brought about by the Electro-pure process in samples of milk leaving the machine, but again there was evidence that further reduction took place after milk left the machine, and this no doubt was due to the exposure in the tank at 70°C. for a few seconds.

Milk "flashed" in ten or in twenty seconds, to 70°C. shows no practical benefit due to holding at that temperature for periods longer than ten seconds. 70°C. for a few seconds appears, therefore, to be the critical point for maximum reduction of bacteria in milk. Milk "flashed" to this temperature gave lower total bacteria counts than milk treated by the Electro-pure process, but again this may be attributed to a slight discrepancy in the time factor.

Study of table 6 reveals the fact that heat alone, regardless of the electric current, can bring about satisfactory reduction of bacteria in milk under conditions of temperature and time approximating those found in the Electro-pure process.

It seems reasonable to conclude from the above studies that it is the high temperature that so effectively destroys bacteria in milk rather than the electric current itself. However the Electro-pure process furnishes a method for producing a very sudden high temperature for a brief period of time and it is felt that the heat thus supplied is very uniformly distributed throughout the milk since every particle of milk must act as the

TABLE 5

*Comparison between milk treated by the electro-pure process and milk "flashed" in the heater at the dairy—two days' run*

| KIND OF SAMPLE AND TREATMENT | EXPERIMENT 1 | | | | | | EXPERIMENT 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature | Bacteria per cubic centimeter, 48 hours 37°C. | Gas in lactose broth | | | Endo's reaction | Temperature | Bacteria per cubic centimeter, 48 hours 37°C. | Gas in lactose broth | | | Endo's reaction |
| | | | 0.1 cc. | 0.01 cc. | 0.001 cc. | | | | 0.1 cc. | 0.01 cc. | 0.001 cc. | |
| | *deg. C.* | | | | | | *deg. C.* | | | | | |
| Raw milk from vat | | 1,400,000 | + | + | + | + | | 100,000 | + | − | − | − |
| | | 1,200,000 | + | + | + | + | | Broken | + | + | − | − |
| | | 600,000 | + | + | + | + | | 100,000 | − | + | − | − |
| | | 1,000,000 | + | + | + | + | | 100,000 | − | + | − | − |
| Electro-treated milk from the machine at | 76 | 5,200 | − | − | − | | 70 | 10,000 | − | − | − | |
| | 74 | 14,000 | − | − | − | | 70 | 11,500 | − | − | − | |
| | 74 | 10,000 | − | − | − | | 70 | 16,000 | − | − | − | |
| | 74 | 5,500 | − | − | − | | 70 | 12,500 | − | − | − | |
| Electro-treated milk from the filler | | | | | | | | 2,500 | − | − | − | |
| | | | | | | | | 3,000 | − | − | − | |
| | | | | | | | | 10,000 | − | − | − | |
| | | | | | | | | 2,500 | − | − | − | |
| Milk flashed to 65°C. and sampled from A* | 65 | 40,000 | − | − | − | | 65 | 13,000 | − | − | − | |
| Milk flashed to 65°C. and sampled from B* | 65 | 35,000 | − | − | − | | 65 | 4,000 | − | − | − | |
| Milk flashed to 65°C. and sampled from C* | 65 | 20,000 | − | − | − | | 65 | 10,000 | − | − | − | |
| Milk flashed to 70°C. and sampled from A | 70 | 1,500 | − | − | − | | 70 | 2,500 | − | − | − | |
| Milk flashed to 70°C. and sampled from B | 70 | 1,500 | − | − | − | | 70 | 2,000 | − | − | − | |
| Milk flashed to 70°C. and sampled from C | 66 | 1,100 | − | − | − | | 70 | 400 | − | − | − | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milk flashed to 75°C. and sampled from | A..... | 75 | 150 | – | – | – | | 75 | 200 | – | – | – |
| | B..... | 75 | 120 | – | – | – | | 75 | 200 | – | – | – |
| | C..... | 70 | 400 | – | – | – | | 75 | 200 | – | – | – |
| Milk flashed to 80°C. and sampled from | A..... | 80 | 200 | – | – | – | | | 200 | – | – | – |
| | B..... | 80 | 200 | – | – | – | | | | | | |
| | C..... | 73 | 50 | – | – | – | | | | | | |

*A refers to flashed milk as it leaves the heater; B refers to flashed milk as it enters the electro-pure machine; C refers to flashed milk as it leaves the electro-pure machine.

TABLE 6

*Comparison between milk treated by the electro-pure process and milk "flashed" in the laboratory*

Experiment 1

| | RAW MILK | ELECTRO-PURE TREATED MILK LEAVING THE MACHINE | | | | ELECTRO-PURE TREATED MILK FROM FILLER | | | | RAW MILK | | MILK FLASHED IN THE LABORATORY IN 10 SECONDS TO 70°C., THEN HELD | | | | | | | RAW MILK | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 38°C. | 70°C. | | | | | | | | 40°C. | | – | 10 seconds | 20 seconds | 30 seconds | 40 seconds | 60 seconds | 90 seconds | 120 seconds | 40°C. | |
| Thousand bacteria per cubic centimeter, 48 hours 37°C. | 550 | 600 | 11 | 15 | 12.5 | 18 | 2 | 3 | 2 | 5 | 1500 | 1800 | 3 | 1 | 0.3 | 0.8 | 1 | 1.6 | 1 | 0.25 | 1000 | 1000 |
| Gas in lactose broth in 0.1 cc. | | | | | | | | | | | | | | | | | | | | | | |
| Gas in lactose broth in 0.01 cc. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Gas in lactose broth in 0.001 cc. | | | | | | | | | | | | | | | | | | | | | | |
| Endo's reaction | +++ | – | – | – | – | – | – | – | – | – | +++ | | – | – | – | – | – | – | – | – | +++ | |

Experiment 2

| | RAW MILK | | ELECTRO-PURE TREATED MILK LEAVING THE MACHINE | | | | ELECTRO-PURE MILK FROM THE FILLER | | | | RAW MILK | | MILK FLASHED IN THE LABORATORY IN 20 SECONDS TO 70°C., THEN HELD | | | | | | RAW MILK | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 38°C. | | 70°C. | | | | | | | | 40°C. | | – | 10 seconds | 30 seconds | 45 seconds | 60 seconds | 120 seconds | | |
| Thousand bacteria per cubic centimeter, 48 hours 37°C. | 600 | 350 | 12 | 10 | 12 | 11 | 9.5 | 6 | 10 | 8 | 480 | 700 | –* | 2 | 2 | 3.5 | 5 | 0.3 | | |
| Gas in lactose broth in 0.1 cc. | – | – | – | – | – | – | – | – | – | – | 0.1 cc. | | – | – | – | – | – | – | | |
| Gas in lactose broth in 0.01 cc. | | | | | | | | | | | 0.01 cc. | | | | | | | | | |
| Endo's reaction | Negative, no growth | | – | – | – | – | – | – | – | – | No growth | | – | – | – | – | – | – | | |

*Forty-eight hour plates broken; same showed 2000 colonies per cubic centimeter after twenty-four hours incubation.

conductor of the electric current. Brevity of heating to a high temperature together with uniformity of distribution of the heat are desirable factors in any flash method of pasteurization of milk.

*2. Chemical changes in the proteins of milk.*

From the literature on the subject of the precipitation of lactalbumin by heat it appears that there is considerable difference of opinion as to just what conditions are required to bring this about. The general opinion, however, seems to be that heating for any considerable time at 68 to 70°C. causes a marked coagulation of albumin. According to Rupp (6) heating milk for thirty minutes at 68.3°C. causes a precipitation of 12.76 per cent of the albumin, while at 71.1°C. 30.87 per cent is coagulated.

It was thought of interest to determine what precipitation of albumin occurred in the Electro-pure process. Table 7 shows the results of analyses of milk before and after treatment by the Electro-pure process at 70°C. In collecting the samples the raw samples were taken from the supply vat after thorough mixing and the treated samples from the bottler.

The methods of analysis used were those used by Rupp in his work. Determinations were run in duplicate. To 10 grams of milk in a beaker 50 cc. of water at 40°C. were added. Next 2 cc. of a solution of potassium alum saturated at 40°C. were added and the mixture allowed to stand for some time to allow the precipitate to settle. The precipitate was then filtered and washed and nitrogen determined on the precipitate plus the filter paper. The nitrogen in the precipitate multiplied by the factor 6.38 gave the amount of casein present.

The albumin and globulin in the filtrate were determined by precipitation with 10 cc. of Almen's tannin solution (5 grams of tannic acid dissolved in 240 cc. of 50 per cent alcohol plus 10 cc. of 25 per cent acetic acid). After the addition of this reagent the mixture, without heating, was allowed to stand over night and then filtered and the precipitate washed. Nitrogen was determined on the precipitate plus the filter paper and the nitrogen in the precipitate times the factor 6.38 gave the amount of

*Forty-eight hour plates broken; same showed 2000 colonies per cubic centimeter after twenty-four hours incubation.
no growth

albumin plus globulin. An observation which might be of interest was that on heating the filtrate from the above filtration a very heavy precipitate formed which resembled very closely the precipitate of albumin and globulin. It was found however that this precipitate contained no nitrogen.

Table 7 shows the results of analysis of milk before and after treatment by the Electro-pure process at 70°C. It will be noted

TABLE 7

*Showing chemical analyses of raw milk and milk treated by the electro-pure process at 70°C.*

| EXPERIMENT NUMBER | CASEIN | | ALBUMIN PLUS GLOBULIN | |
|---|---|---|---|---|
| | Raw | Treated | Raw | Treated |
| | *per cent* | *per cent* | *per cent* | *per cent* |
| 1 | 2.45 | 2.49 | 0.608 | 0.598 |
| | 2.46 | 2.48 | 0.581 | 0.590 |
| Average..... | 2.455 | 2.485 | 0.594 | 0.594 |
| 2 | 2.38 | 2.39 | 0.574 | 0.538 |
| | 2.36 | 2.36 | 0.553 | 0.547 |
| Average..... | 2.370 | 2.375 | 0.563 | 0.542 |
| 3 | 2.30 | 2.26 | 0.600 | 0.593 |
| | 2.36 | 2.37 | 0.609 | |
| Average..... | 2.330 | 2.310 | 0.604 | 0.593 |
| 4 | 2.81 | 2.80 | 0.866 | 0.855 |
| | 2.81 | 2.80 | 0.852 | 0.843 |
| Average..... | 2.810 | 2.800 | 0.859 | 0.849 |
| Average..... | 2.491 | 2.493 | 0.655 | 0.645 |

Protein = Nitrogen × 6.38.

that there is very little change in the amount of casein although the average shows a very slight increase which would indicate some precipitation of albumin. The albumin is apparently changed very slightly. The variation is so slight, however, that it is possibly within experimental error. There is, however, a

fairly consistent reduction of albumin after treatment. The average reduction is 0.01 per cent.

The above analyses show that the precipitation of albumin in the Electro-pure process at 70°C. is very slight if any.

### *3. Effect of Electro-pure process on constituents and properties of milk not considered previously*

*a. Acidity and fermentation test.* The so-called "keeping quality" of milk is an important consideration in commercial work. It has already been shown in a previous experiment that milk treated by the Electro-pure process and kept in a refrigerator shows no change evident to smell or taste and remains palatable for about five days. But how would the Electro-pure milk behave at room temperature? To answer this question several samples of raw and electro treated milk were collected on different days, tested and allowed to stand at room temperature in the glass stoppered sampling bottles in which they were collected.

The acidity of fresh samples of milk and of twenty-four and forty-eight hour samples kept at room temperature was determined by titrating, in duplicate, 10 cc. of milk with N/10 alkali, using phenolphthalein as an indicator.

The results obtained are shown in table 8. A slight decrease in titrated acidity was observed in nearly all samples of freshly electro treated milk as compared to the original raw milk. Raw milk curdled within twenty-four hours at room temperature, and, occasionally, with high acidity or with gas pinholed in the curd, while milk electro treated at 70°C. showed but a slight increase in acidity and gave no indication of changes evident to taste or smell in twenty-four hours at room temperature but showed a normal curd and high acidity in forty-eight hours. Milk electro treated at 74°C. which is somewhat higher than the temperature ordinarily used in the Electro-pure process gave indications of a slight increase in acidity in forty-eight hours at room temperature, and formed a soft curd on the third day.

It may be said then that milk treated by the Electro-pure

TABLE 8

*Keeping quality of electro-pure treated milk at room temperature*

| MILK | N/1 NaOH TO NEUTRALIZE 100 CC. OF FRESH SAMPLE | N/1 NaOH TO NEUTRALIZE 100 CC. OF MILK HELD AT ROOM TEMPERATURE FOR | | | FERMENTATION IN MILK AT ROOM TEMPERATURE IN | |
|---|---|---|---|---|---|---|
| | | 24 hours | 48 hours | 72 hours | 24 hours | 48 hours |
| | *cc.* | *cc.* | *cc.* | *cc.* | | |
| Raw | 2.2 | 7.0 | 8.5 | | Curdled | |
| Electro-treated at 70°C | 2.0 | 2.8 | 8.0 | | Off smell | Curdled |
| Raw | 2.5 | 6.0 | 9.0 | | Curdled | |
| Electro-treated at 70°C | 2.3 | 2.7 | 8.5 | | No change | Curdled |
| Raw | 2.6 | 9.0 | 10.0 | | Curdled | |
| Electro-treated at 70°C | 2.4 | 2.4 | 8.5 | | No change | Curdled |
| Raw | 2.5 | 7.0 | 9.5 | | Curdled | |
| Electro-treated at 70°C | 2.4 | 2.5 | 8.0 | | No change | Curdled |
| Raw | 2.5 | 6.3 | 9.0 | | Pinholes in curd | |
| Electro-treated at 70°C | 2.3 | 2.3 | 4.5 | | No change | Sour taste |
| Raw | 2.5 | 6.5 | 9.5 | | Pinholes in curd | |
| Electro-treated at 70°C | 2.2 | 2.2 | 7.5 | | No change | Curdled |
| Raw | 2.4 | 6.5 | 8.5 | | Curdled | |
| Electro-treated at 74°C | 2.3 | 2.6 | 2.6 | 4.0 | Cooked taste | Soft curd on 3d day |
| Raw | 2.2 | 5.5 | 8.0 | | Sour smell | Curdled |
| Electro-treated at 74°C | 2.3 | 2.4 | 2.3 | 2.5 | Off taste | Soft curd on 3d day |
| Raw | 2.0 | 4.2 | 8.2 | | Off smell | Curdled |
| Electro-treated at 75°C | 2.1 | 2.1 | 3.4 | | No change | Bad taste |

process at 70°C. shows practically no change in twenty-four hours at room temperature, but sours and curdles normally in forty-eight hours at room temperature.

A study of the effect of the Electro-pure process on cream line, coagulation with rennin and enzymes was the next step in this investigation. Representative samples of raw milk were collected from the mixing vat at the dairy and of electro treated milk at 70°C. from the "Milwaukee" filler. These samples were tested in duplicate and the experiment repeated on three days. Data thus secured is given in table 9.

*b. Cream line.* Bottled milk possesses a decided asset in a clear, deep cream line. In order to determine how the Electro-pure process affects the cream line, 100 cc. quantities of raw and electro treated milk were placed in 100 cc. graduated cylinders and set aside in a quiet place in the laboratory. At the expiration of one hour readings were made. Table 9, shows the raw and the corresponding electro treated samples to be of the same fat content, as determined by the Babcock test, and the same specific gravity. All samples tested in this experiment gave a cream line with a cream column of 10 cc. It seems, therefore, that the Electro-pure process in no way interferes with the cream line in milk, electro treated at 70°C.

*c. Coagulation with rennin.* Next came the question of coagulation of electro treated milk with rennin. Armour's powdered rennin (1:30,000) was used. A 20 per cent stock solution was prepared from it and kept in the ice box. When needed, 1 cc. of this was diluted in 100 cc. of cold sterile water, and 5 cc. of the latter were used for every 250 cc. of milk at 30°C. thus really giving 1 part of powdered rennin to 25,000 parts of milk, instead of 1:30,000 as called for on the label. The milk and rennin solution were thoroughly mixed and placed in a large funnel to which a 0.01 cc. capillary pipette had been attached. This arrangement gave a fine steady stream of milk, which stopped flowing when the milk coagulated. All samples were tested in duplicate. Time was noted when the rennin was added to the milk and when the milk stopped flowing through the capillary pipette. The results of these experiments emphatically show

TABLE 9

*Effect of the electro-pure process on certain constituents and properties of milk*

| EXPERIMENT | | CREAM IN 100 CC. OF MILK AFTER STANDING 1 HOUR | FAT IN MILK | SPECIFIC GRAVITY | N/1 NaOH TO NEUTRALIZE 100 CC. OF MILK | FERMENTATION TEST | | | COAGULATION WITH RENNIN IN | PEROXIDASE TEST | REDUCTASE TEST |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 24 hours | 48 hours | | | |
| | | *cc.* | *per cent* | | *cc.* | | | | *minutes* | | |
| 1 | Raw milk | 10 | 3.5 | 1.029 | 2.5 | Pinholes in curd | + | | 28 | + | + 25 min. |
| | Electro-treated milk at 70°C. | 10 | 3.5 | 1.029 | 2.2 | Normal curd | − | + | 47 | + | + 1 hour |
| 2 | Raw milk | 10 | 3.9 | 1.029 | 2.2 | Gassy curd | + | | 31 | + | + 36 min. |
| | Electro-treated milk at 70°C. | 10 | 3.9 | 1.029 | 2.0 | Normal curd | − | + | 60 | + | − after 1 hour |
| 3 | Raw milk | 10 | 3.4 | 1.029 | 3.1 | Pinholes in curd | + | | 15 | + | + 36 min. |
| | Electro-treated milk at 70°C. | 10 | 3.4 | 1.029 | 2.3 | Normal curd | − | + | 63 | + | − after 1 hour |

that the Electro-pure process of treating milk, at 70°C., delays the coagulation of milk with rennin.

*d. Peroxidase test.* Wilkinson and Peter's method (7) for the detection of peroxidase in milk was used.

To 10 cc. of milk add 1 cc. of a 10 per cent solution of benzidine in 96 per cent alcohol, 3 drops of 30 per cent acetic acid and, finally, 2 cc. of 3 per cent hydrogen peroxide. Peroxidases produce a blue coloration which is usually localized in the precipitated caseinogen.

Results obtained with this test show that peroxidase is not destroyed in milk treated by the Electro-pure process at 70°C. The blue coloration is apparently as marked in the treated as in the raw sample.

*e. Reductase test.* In testing for reductase in milk the method given by Race (7) was followed.

To 10 cc. of milk add 1 cc. of Schardinger's reagent (190 parts water and 5 parts each of formalin and a saturated alcoholic solution of methylene blue) and heat to 43 to 45°C.; the time required for decolorization is noted. The reoxidation of the surface layers by the air may be entirely prevented by adding a small quantity of paraffin, but the cream layer usually gives the necessary protection.

According to Race, Schardinger's reagent allows reductases of cell origin to function, but does not allow reductases of bacterial origin to act. He adds that there is no relation between the bacterial content of milk and the reductase test.

Results of this experiment, recorded in table 9, show that the Electro-pure process of treating milk at 70°C. evidently weakens the reductase, as shown by prolonged time required for decolorization.

### *4. Nutrition tests*

An important consideration in connection with any method of treating milk is whether or not the process causes any change in feeding value. It was thought very desirable to determine whether or not the Electro-pure process reduced the feeding value of the milk treated. The experimental work on this phase of the subject was conducted by Dr. E. V. McCollum in

his laboratory at Johns Hopkins University, School of Hygiene and Public Health, Baltimore, Md. Two types of experiments were run, one with milk electro treated at 70°C. and the other with butter made in this laboratory from cream from electro treated milk at 70°C. The following statement is taken from a letter from Dr. McCollum in which he reported the results of his tests.

> We have conducted two types of experiments with the materials which you sent me. In one we fed young rats on a diet which was faulty in such a way as to produce experimental beri-beri or polyneuritis. When the animals were in an enfeebled condition and near the point of showing paralysis we added to their diet the milk pasteurized by your Electro-pure process. In all cases they were able to respond immediately with growth, and remained for two weeks in a normal condition.
>
> The other type of experiment which we conducted was that of feeding young rats a diet faulty in such respects as to produce the peculiar eye disease—xerophthalmia, which is due to the lack of the unidentified dietary essential peculiar to certain fats, among which butter fat is the best source. When the eyes were swollen shut and death was imminent they were given your butter and in all cases the eyes were cured and the animals returned to a normal condition.
>
> It is our firm belief that this milk and the butter made from it have essentially the same dietary properties as have pasteurized milks of good quality in general.

The results of the above tests indicate that milk treated by the Electro-pure process is satisfactory from the standpoint of feeding.

The authors wish to express their thanks to Dr. E. V. McCollum who so kindly conducted the nutrition tests here reported; to Captain Carrol Powers and to Mr. W. C. Handly for their willing coöperation at the plant and to Sergeant George H. Brandes for his assistance in making the chemical determinations here reported.

## DISCUSSION

From the results of the above experiments it appears that the Electro-pure process produces a satisfactory reduction of bacteria in milk and for the most part little change in composition and properties. It should be emphasized that all the tests were run with the machine in actual plant operation but at each time when tests were made it was made sure that everything was running in a proper manner. Temperatures were always taken with the same, good grade thermometer so that the temperatures here reported are accurate. It is therefore felt that the results here reported express what the machine is capable of doing when operating under the certain conditions here indicated.

One of the claims made for the Electro-pure process is that the electric current as such is what destroys the bacteria. The experiments performed indicate very conclusively that the current alone has very little if any bactericidal property. This differs from the conclusions reached by Beattie in his work. He claims that the current does play an important part in the reduction of bacteria. However in his work he used 3600 to 4200 volts and 2 to 2.3 amperes with a rapidly alternating current. It should be noted that the Electro-pure process as studied here does not duplicate these conditions. In the first place the 25 cycle current used here could not be called rapidly alternating and in the second place the voltage here is much less than that used by Beattie. It would be of interest to duplicate the work in this report using the conditions specified by Beattie.

A feature of the problem which is very important but which was not investigated is the matter of pathogenic organisms. Although the good results with regard to the reduction of B. coli would indicate that the process would likely eliminate such organisms as B. typhosus, still the only way to make sure would be to try it out. Inoculation experiments with B. tuberculosis should also be performed.

It should be of interest to know what the machine is doing in actual practice. In this laboratory samples of milk taken at random are analyzed daily. These results should show what

the machine is actually doing on a commercial basis. In January the Camp was supplied with pasteurized milk from Baltimore. The average bacteria count after forty-eight hours on agar for this month was about 56,000 per cubic centimeter. For the month of February the Camp was supplied with milk treated by the Electro-pure process. The average bacteria count for this month was about 18,000 per cubic centimeter. This shows quite an improvement over the results of the previous month on pasteurized milk from Baltimore.

However since the first of March the machine has not been putting out, uniformly, a satisfactory product. The average bacteria count for the month of March was about 169,000 and for April 234,000 per cubic centimeter. These high averages are due largely to several high counts scattered throughout the months. On most days the bacteria counts were well below these averages but the scattered high counts were distributed sufficiently to show that the process has not been reliable the past two months. Whether this is due to fault of the machine, to fault of operation or to poor quality of raw milk treated, is difficult to say. It is felt that improvement can be made in the construction of the machine especially with reference to a means of temperature control. There should be some device to assure a uniform heating and to prevent milk which has not reached the proper temperature from being delivered to the bottler.

A very important defect which has been noticed with regard to the machine and one which, it is felt, has contributed to the poor showing made by the machine during the past two months is that milk in passing down the series of cups has a tendency to spatter and in this way moisten the stand on which the cups are placed. This moistening has produced a short circuit which of course has interfered with the proper operation of the machine. At times when the short circuiting has been sufficient the wiring has burned out with what might be called explosive violence which might have proven dangerous had an operator been close at hand. It is felt that this difficulty could be eliminated with a proper construction of cups to prevent spattering and with the stand for the cups made of some such material as plate glass

rather than of wood. It is possible that the whole explanation for the poorer results in March and April lies in the fact that it took about a month for the stand to become water soaked and that as time went on this condition became worse. With a water soaked condition of the stand, through which the wiring passed, much of the current would undoubtedly pass through the water soaked board instead of through the flowing milk, with the results which are so evident in the average bacteria counts for March and April. At the present writing the machine is not in operation but is awaiting repair along the lines indicated in the above discussion.

It is felt therefore that from a practical standpoint the Electro-pure machine in operation in this plant has not proven entirely successful in the long run. Modifications in construction must be made before the machine can be considered a commercial success.

## CONCLUSIONS

1. The Electro-pure process conducted under the conditions indicated in these experiments gives a very satisfactory reduction of total count in good raw milk, a satisfactory reduction in poor raw milk and at the same time effectively destroys nearly all lactose fermenting, Endo positive organisms in raw milk.

2. Milk issuing from the different units of the Electro-pure machine is fairly uniform in bacteria count.

3. Electro treated milk kept at 5 to 10°C. keeps well for about five days.

4. At room temperature electro treated milk showed no change in twenty-four hours but soured normally in forty-eight hours.

5. The destruction of bacteria in the Electro-pure process is apparently due to the heat produced by the electric current rather than to the electric current itself. The Electro-pure process furnishes a method for producing a very sudden high temperature for a brief period of time.

6. The precipitation of albumin by the Electro-pure process at 70°C. is very slight if any.

7. The time required for coagulation by rennin is decidedly increased after treatment by the Electro-pure process at 70°C.

8. The Electro-pure process at 70°C. does not interfere with the cream line of milk.

9. The Electro-pure process at 70°C. apparently does not destroy the peroxidase in milk but weakens the reductase.

10. The Electro-pure process has no effect on the feeding value of milk.

11. From a practical standpoint the Electro-pure machine in operation at this plant has not proven entirely successful in the long run. Modifications in construction must be made before the machine can be considered a commercial success.

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# THE MOULD OF THE BLUE-VEINED CHEESES

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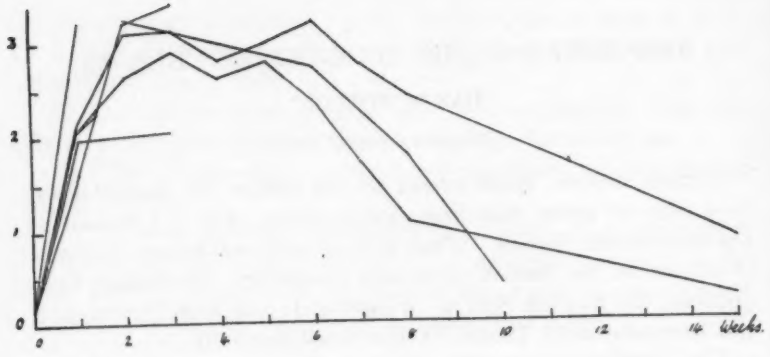
Certain cheeses, much prized by the public, are characterised by a blue or green marbling, due to which they are classed as the blue-veined cheeses. They include such well-known varieties of cheese as the French ewes-milk Roquefort, the Italian Gorgonzola, the English Stilton, Wensleydale and blue-Dorset, and the less commonly known Welsh blue-Caerphilly.

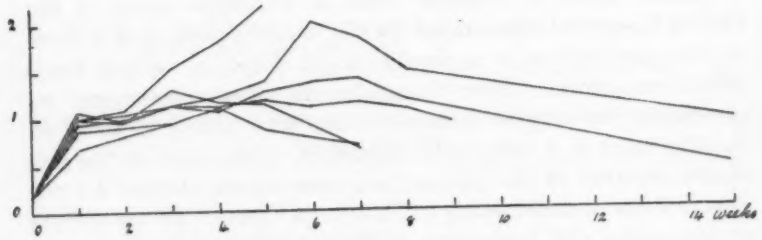
The marbling is caused by the growth of a mould usually still referred to in this country as Penicillium glaucum; but this name is too general as it embraces several distinct varieties of Penicillium mould.

Charles Thom in America made an extensive study of the French Roquefort cheese and always found present in it a more or less pure culture of a specific mould which he termed Penicillium roqueforti. Even though many other species may be present in the original milk no other blue mould is likely to develop much in a well-made Roquefort cheese, due to the low oxygen content of the gas in the spaces of the cheese; 2.4 per cent to 7 per cent according to Thom and Currie. Of the species of Aspergillus and Penicillium studied the Roquefort mould was the only one capable of producing fairly strong colonies in air containing only 5 per cent of free oxygen. Owing to the great bacterial activity of the freshly made cheese the oxygen of the spaces may fall below 5 per cent; and even P. roqueforti refuses to grow in an oxygen-less atmosphere. For this reason it is usual to punch the young cheeses with wires to permit a temporary circulation of air and the outer ends of the skewer holes get filled up during the subsequent handling of the cheeses. The pricking is now done in the Roquefort district by means of machines.

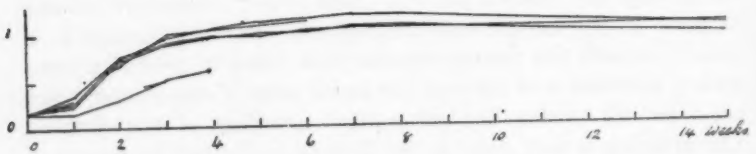
These experiences are specially interesting to us, for Thom on examining an English Stilton, an Italian Gorgonzola, and a




Development of Acidity at Blood Heat 98°F.




Development of acidity at Room Temperature 56-70°F.




Development of Acidity in Cold Storage 32-42°F.

Hungarian Brindze, found the Roquefort mould to be dominant in each. Paul Daire (Les microbes dans l'industrie laitière, p. 107, 1914) refers to the spores of P. roqueforti as being the cause of the green marbling of Roquefort, Gex, Sassenage, Mont Cenis, Septmoncel, Gorgonzola, Stilton, etc.

These blue cheeses have a characteristic sharpish peppery taste which has been the subject of experiments by James N. Currie. He found that P. roqueforti produces a water-soluble lipase which is the chief factor in the hydrolysis of fat during the ripening of Roquefort cheese; this results in an accumulation of caproic, caprylic and capric acids which, with their readily hydrolisable salts, have a peppery flavour. Other known results of the work of this mould are, that it is able to destroy the acidity in cheese curd, and that it produces proteolytic enzymes which attack the casein compounds of the curd and thus help to ripen the cheese.

The cultural characters of the mould (Thom) are as follows:

Colonies on potato agar or lactose gelatine quickly turn green, becoming a dirty brown with age, velvety strict, indeterminately spreading by large main radiating branching hyphae, giving a somewhat uneven and indefinite margin, which gets a white fibrous almost spider-web appearance from its alternation of submerged parts of hyphae with short prostrate aerial loops. Reverse of colony yellowish white. Colonies do not liquefy sugar gelatine though they soften it somewhat. Fungus on plain gelatine or potato agar changes litmus from red to blue very rapidly and strongly almost from the beginning of the growth. Fruiting period short; but one crop of spores upon the mycelium. Cosmopolitan and omnivorous or nearly so. Characteristic of Roquefort and related types of cheese. The mould digested milk or curd rapidly, and gave a characteristic growth at 5 to 10°C. It grew well when the carbon was supplied as butter fat; but weakly when it was supplied as lactic acid or lactose.

A few blue cheeses have been examined here to see whether the Roquefort mould was dominant in them and the results are summarised below. Penicillium moulds other than roqueforti were not differentiated:

| | VARIETY OF CHEESE | DOMINANT MOULD |
|---|---|---|
| 1 | Roquefort | P. roqueforti |
| 2 | Roquefort | P. roqueforti |
| 3 | Gorgonzola | P. roqueforti |
| 4 | Gorgonzola | P. roqueforti |
| 5 | Stilton | P. roqueforti |
| 6 | Stilton | P. roqueforti |
| 7 | Stilton | P. roqueforti along with two other Penicillium moulds |
| 8 | Stilton | P. *not* roqueforti |
| 9 | Wensleydale | P. *not* roqueforti |
| 10 | Blue Caerphilly | P. roqueforti |
| 11 | Blue Caerphilly | P. roqueforti and traces of another Penicillium mould |
| 12 | Blue Caerphilly | P. *not* roqueforti |

Of the dozen blue cheeses examined the Roquefort mould was thoroughly dominant in eight, was present in another, but was apparently absent from three. Of these latter three the blue Caerphilly and Wensleydale had not typical veins; but the Stilton seemed quite normal and the appearance of the wrong mould on the plates was a surprise. A Penicillium mould from the eyes of a Gruyère cheese was not the Roquefort mould. No Aspergillus mould was found in any of the cheeses.

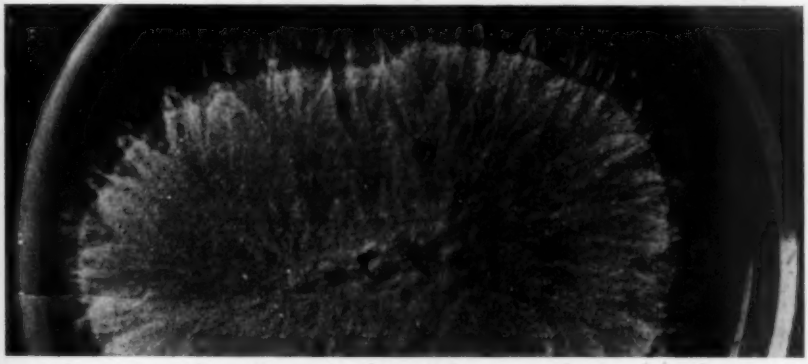
Several whey sugar plates were inoculated from the veins of each cheese and the mould allowed to develop at room temperature. There was no difficulty in distinguishing the Roquefort mould due to the low habit of growth (capacity to fruit in a narrow space) and the spider-webby appearance of the growing mycelium. The accompanying photograph shows the P. roqueforti (Thom) from a blue-Caerphilly cheese.

The Roquefort mould on whey agar plates was found to produce coloured fructifications within a fortnight in cold storage. Whey agar "slants" showed no coloration in fourteen days at blood heat; but the mould grew normally on the tubes being transferred to room temperature. Whey agar plates were kept (in the dark) at room temperature for months, yet subcultures

showed that the spores survived quite a long time as the following data show:

| SUCCESSFUL SUBCULTURE OBTAINED ON | FROM PLATES INOCULATED ON | SOURCE OF MOULD |
|---|---|---|
| June 20, 1917 | October 3, 1916 | Roquefort |
| June 20, 1917 | November 15, 1916 | Stilton |
| June 20, 1917 | October 9, 1916 | Gorgonzola |

Under similar circumstances the spores of the Camembert mould were found to be alive at the end of four months, of



*A*, Site of Inoculation, *B*, Colored Area Due to Spores; *C*, Growing Mycelium

Mucor mucedo at end of seven months, and of an Aspergillus culture at the end of nine months. In each case the spores have probably a still longer life.

In cheese the Roquefort mould develops first in the centre where the texture is more open and then extends outwards and finally from skin to skin. When a cheese is skewered one finds an excellent development of mould along the skewer marks. This can usually be demonstrated in Gorgonzola. The idea that the mould can be introduced into the cheese by means of wires is probably quite wrong; at best the skewering merely enables the mould already in the cheese to proliferate and fructify.

The most important practical point which arises in this connection is—How does the mould get into the cheese? In the first place the spores may get into the *milk* in the cow-house or subsequently. Then in the making of Gorgonzola or Stilton cheese the *curd* is left lying about a good deal exposed to the air of the dairy and in this way more mould spores are acquired. Blue-veined cheeses are often made by a two-curd process (Gorgonzola, some Stiltons and blue-Caerphillies); one curd lies about a long time and is then mixed with a sweeter, moister curd before moulding. On the other hand the Roquefort cheese makers inoculate the curd, while the moulds are being filled, with dry powdered bread in which the mould has been cultivated.

In 1916 we started making blue cheeses (Wensleydales and Stiltons) in a new dairy and in order to insure a copious growth of mould we (Miss H. M. Williams, N.D.D., was cheese maker) inoculated the curd with pure cultures of P. roqueforti. The cultures were obtained from an excellent Gorgonzola, were propagated on whey agar plates at room temperature and were used when a few weeks old. The Petri-dishes were simply opened and shaken over the curd before moulding. This method of inoculation had been previously tested in the laboratory on sterile whey agar plates, and a good growth of the mould on these resulted.

Mr. Richard Thomson of the Direct Trading Company, who bought most of these cheeses, subsequently gave them an excellent report:

> The cheeses were kept in our warehouse where we have no artificial heating. We did not skewer the Wensleydales, yet we found that they developed a nice mould and were much appreciated by our customers who had previously been in the habit of buying Gorgonzola cheese. The Stiltons we had from you gave every satisfaction and ripened well.

A few Stiltons sold individually also did well. The fresh cheeses had not been skewered in the dairy.

The uniformly successful results obtained with these Stiltons and Wensleydales we attributed largely to the use of pure cul-

tures of the mould. The acidity of the curd at moulding is usually considered to be important if the mould is to grow well but considerable latitude may be allowed as the following figures from Miss Williams' records show:

| ACIDITIES AT MOULDING | WENSLEYDALE | STILTON |
|---|---|---|
| | *per cent* | *per cent* |
| Maximum | 0.65 | 0.90 |
| Average | 0.44 | 0.62 |
| Minimum | 0.30 | 0.20 |

After the curd is moulded the whey draining from the Stiltons a few days later may show 2 per cent of acidity.

Penicillium roqueforti (Thom) apparently plays an important part in the ripening of our best English blue-veined cheeses. In this no doubt, it is assisted by the lactic bacteria and the pepsin enzyme of the rennet extract. Oidium lactis is quite common in Stiltons; it is not eliminated by the low oxygen content of the air spaces and Thom suggests getting rid of it by heavier salting. It is apparently always present in milk. Preliminary experiments in the laboratory here however, suggest that this little white mould may play an important part in the formation of the characteristic crinkled coat of Stiltons.

At the end of February plates were exposed to the air of the dairy and others were inoculated from the outside of some Caerphillies on which a blue mould was growing. We hoped that the Roquefort mould had become thoroughly established in the dairy, but the dominant Penicillium mould which developed on the plates was not the Roquefort mould.

Under these circumstances we have again been using pure cultures of the Roquefort mould this summer (from blue Caerphilly this time) for preparing Stilton, Wensleydale and imitation Roquefort cheeses. A *single curd* "blue-Caerphilly" was also made; these in ordinary practice are seldom found to go blue satisfactorily. Cultures of the mould developing in these cheeses were made to show if possible that it was always the Roquefort mould; the cheeses ripened satisfactorily and on

examining a cheese of each variety made the Roquefort mould was found to be dominant and indeed was the only mould present.

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# THE PREPARATION OF A DAIRY EXHIBIT

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## INTRODUCTION

Every agricultural college desires not only to keep its constituents who are interested in the work of the institution fully informed of developments in its work, but it is also the constant aim of the college to acquaint and interest a larger proportion of the people of the state in its various activities. While many people will read carefully an unadorned pamphlet or magazine article, the illustrated article or the story told almost entirely by pictures will reach a larger audience. Persons who read little often learn much from a display of models, and from graphic charts, lectures and demonstrations. These are some of the reasons why well executed exhibits may aid an institution or department in strengthening its relations with its constituency.

## OBJECT SHOULD BE DEFINITE

In planning a dairy exhibit the object of the display and the conditions under which it is to be presented should be kept definitely in mind. In general, dairy exhibits should serve two purposes, first, that of being suitable for display at fairs, short courses, etc., in any part of the state, or at national shows, and secondly, that of serving to illustrate the work of the department to those who visit the institution.

A traveling exhibit is usually designed to familiarize the persons seeing the display with the functions of the department rather than attempting to present a large mass of details on various subjects, and to establish contact with such persons by encouraging them to write for further information, bulletins, etc. Exception to this rule is sometimes made when it is desired to present detailed data on some one subject of immediate moment. Figure 1 illustrates an exhibit of this character. At

the time this exhibit was presented, the public was so intensely interested in the cost of milk production that this one subject exhibit attracted a great deal of attention.

A stationary exhibit located at the agricultural college may well be made more extensive than the traveling exhibit and cover the work of every division of the department, in detail.

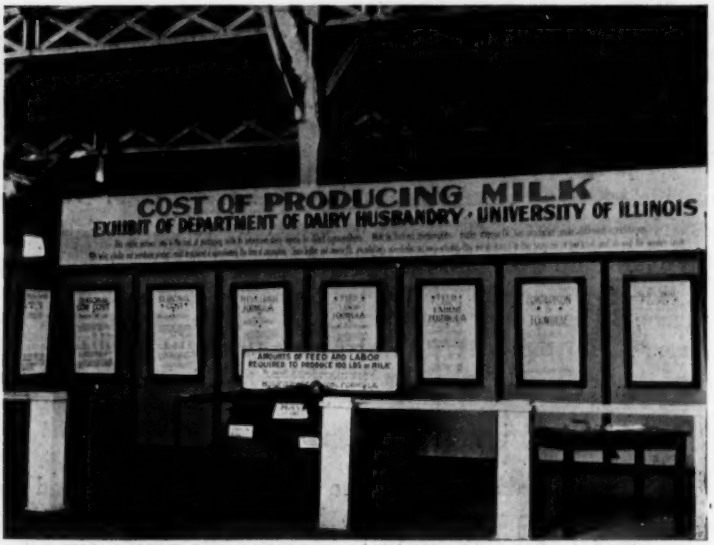


FIG. 1. AN ATTRACTIVE ONE SUBJECT EXHIBIT

The charts and signs were lettered by hand in two colors. The background consists of wall board panels held in place by wood strips, and was painted to correspond to the general color scheme of the exhibit.

## QUALITIES OF A GOOD EXHIBIT

Above all, a successful exhibit must attract and hold the attention of spectators for a few moments at least. Of course those not interested in the information presented will pass on after learning the character of the exhibit, but some especially striking or unusual features should be employed to attract the attention of all passersby. The subject matter of the exhibit

may be of the very best, but the exhibit will be of little value unless it appeals to and reaches the people for whom it was planned.

Some of the means commonly employed to attract attention are: Moving objects, such as moving pictures, moving mechanical contrivances, people at work, animals, etc.; light and color,

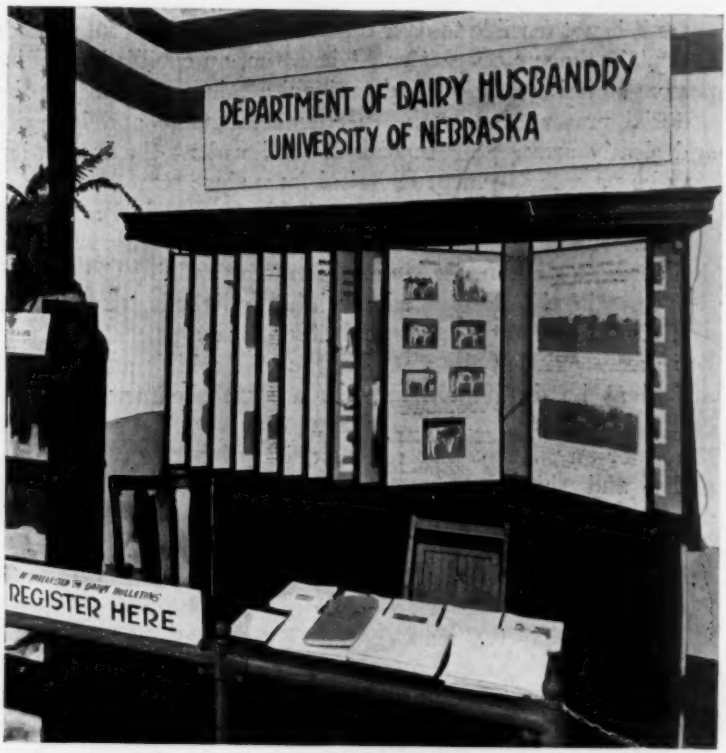


FIG. 2. AUTOMATIC DISPLAY FIXTURE

This fixture combines the three desirable qualities of color, light and motion. The wings are turned automatically by a small motor, a wing being turned about every ten seconds. The charts, many of which are in color, are protected by glass. A pendant switch is connected to the motor by a long cord so that the machine may be stopped at any point by the attendant. The canopy, which carries electric lights, and the cabinet wood base are finished in mahogany.

such as colored transparencies, growing plants, colored charts, electric signs, etc.; moving objects combined with light and color, such as moving colored charts, artificially lighted; sound, such as a spoken explanation during a demonstration, noise made by a mechanical device, and music.

Another essential quality of a good exhibit is clearness. Traveling exhibits especially must be almost self-explanatory. Oftentimes it is not feasible to have a person constantly in attendance to explain the subject matter. Then, too, an exhibit is seen by persons differing widely in educational attainments, so that the material presented must be in simple language and logically and clearly arranged. An exhibit stationed at the institution may be prepared in more technical form since some member of the department will usually be available to explain it.

On account of the large amount of work required to arrange and decorate a booth, etc., in addition to assembling the exhibit, it is essential that the traveling exhibit be light in weight, have a minimum amount of glass and other breakable material, and be so arranged that the assembling of the exhibit matter upon arrival at its destination may be accomplished speedily and easily. If charts are to be shown, they should be placed in frames or on panels which can be quickly hung or set up upon arrival and which form part of the decorative scheme for the exhibit.

An exhibit which is part of a fair or exposition where people spend but a little time viewing each feature must be of such character that the spectator is able to grasp the lesson quickly. This means that the reading matter must be condensed and reduced to a minimum. People do not care to stop to read a lengthy dissertation but usually are attracted by fine illustrations and life size articles or miniature models of buildings, equipment, etc., and will often spend several minutes watching some simple mechanical contrivance from which they could grasp the leading thought almost at a glance.

It is perhaps needless to add that a good dairy exhibit is up-to-date, presenting live subjects which are of value to the dairy industry at the time. While there are certain dairy sub-

jects which will doubless require emphasis for many years to come, such as production and care of clean milk and cream, feeding, calf rearing, etc., yet the exhibit may be improved by stressing those subjects under discussion at the time, such as pure-bred bull campaigns, calf clubs, cow testing associations, etc.

### SELECTION OF FIXTURES FOR CHARTS

The size and shape of the fixtures or frames which are to carry the charts will largely determine the size and shape of the cards used in making the charts. It is best to have as great a degree of uniformity in the physical makeup of the exhibit as possible, as standardized charts can be readily changed in position or made over to keep them up-to-date, besides rendering the exhibit more attractive in appearance. When hand lettering or gummed letters are to be employed in making the charts, it is much more convenient to use horizontal panels, that is, having the horizontal dimension greater than the vertical. It is difficult to letter tall vertical panels such as those illustrated in figure 2. The most satisfactory method of lettering such panels, when gummed letters are used, is to place the card on a table with the top turned toward one and do the lettering on the upper part of the card by placing the letters upside down and from right to left. The card may then be reversed and the lettering on the lower half completed in the normal manner. However, a horizontal panel 24 inches or less in height may be laid in front of one on a desk and be conveniently lettered without turning the card. The horizontal panel also offers an advantage in allowing longer lines for lettering, causing fewer breaks and divided words. Figure 3, at the left, illustrates a three section folding fixture, which, when removed from the shipping case and stood upon the floor is self-supporting and requires no further preparation. One wing has been removed from the fixture at the right. The cards on which the charts for these fixtures were made are 20 by 38 inches in size, a convenient size for lettering, but larger cards could be used if desired. The headings are 12 by 38 inches. Black enameled metal strips are used for borders

FIG. 3. A STATE FAIR BOOTH

The decorations consist principally of one three-panel and one two-panel folding fixtures which were simply set up along the walls.

and to hold the cards in place. The frames of the charts shown in figure 1 consist of 3-inch plain wood strips and were made at a carpenter shop. They were afterwards stained. Both of these fixtures fulfill the requirements of being relatively light, fit standard hinged cover shipping cases, and are ready to p'ace upon arrival.

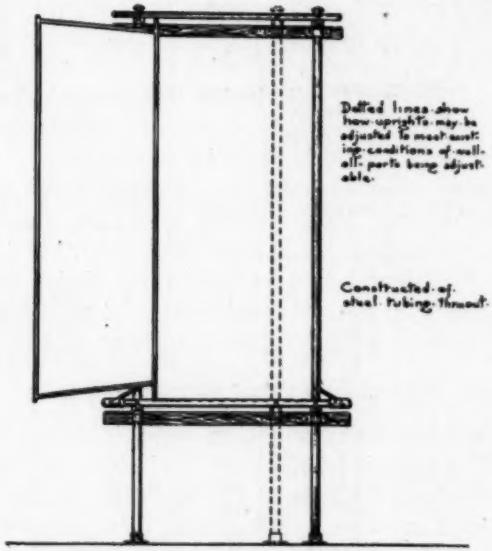
Dotted lines show how uprights may be adjusted to meet existing conditions of wall all parts being adjustable.
Constructed of steel tubing throughout.
·ADJUSTABLE·
·WALL·MULTIPLEX·NO·20·

FIG. 4. ADJUSTABLE WALL FIXTURE

The frame may be secured in any desired length and is adjustable to any standard size wing (courtesy Multiplex Display Fixture Company).

For a stationary exhibit much more elaborate fixtures may be used. The display fixture illustrated in figure 2 is mounted on a cabinet wood base and carries 12 wings which provide 24 display surfaces each 26 by 44 inches in size. It occupies a floor space approximately 3 by 8½ feet. The wings are turned automatically by means of a small motor. The canopy above is provided with

The decorations consist principally of one three-panel and one two-panel folding fixtures which were simply set up along the walls.

electric lights and reflectors to brightly illuminate the charts. For museum or office use a fixture such as the one illustrated in figure 4 is very convenient. It consists of an adjustable wall frame of any desired length, carrying pivoted wings which may be turned by hand. The wings are provided with either steel channels to carry removable cardboard fillers and glass or else solid board or composition filler on which charts may be fastened by means of clamps or thumb tacks. Cork board fillers especially designed for use with push pins and map tacks are als on the market. Fixtures for displaying transparencies are of many styles, but as a rule those which have four or more display sides and occupy positions such that the visitor may walk around them are more economical of light than wall fixtures having but one display surface. Many kinds of cases for displaying models and articles of various kinds may be secured, but in order to maintain a high degree of excellence in this kind of an exhibit it is essential that the cases themselves present a neat, substantial appearance and furnish ample protection from dust and handling.

### ARRANGING THE SUBJECT MATTER

When a traveling exhibit is to be shown in the same localities in consecutive years it is, of course, desirable that not only the subject matter but the form of the exhibit be varied somewhat from year to year. As suggested above it may also be desirable to devote a large part of the exhibit to a subject which is uppermost in the mind of the public at that time. As a rule it is always well to include some reference to the functions of the department or institution making the exhibit, the services which can be rendered, and the address of the department. One must keep in mind in preparing such an exhibit that in almost every state there are thousands of persons who do not know of the existence of their state university, much less its functions and location.

The stationary exhibit offers many possibilities since more bulky and also more fragile material may be included than in the traveling exhibit. One subject which can be displayed to advantage on the wall frames is the extension activities of the

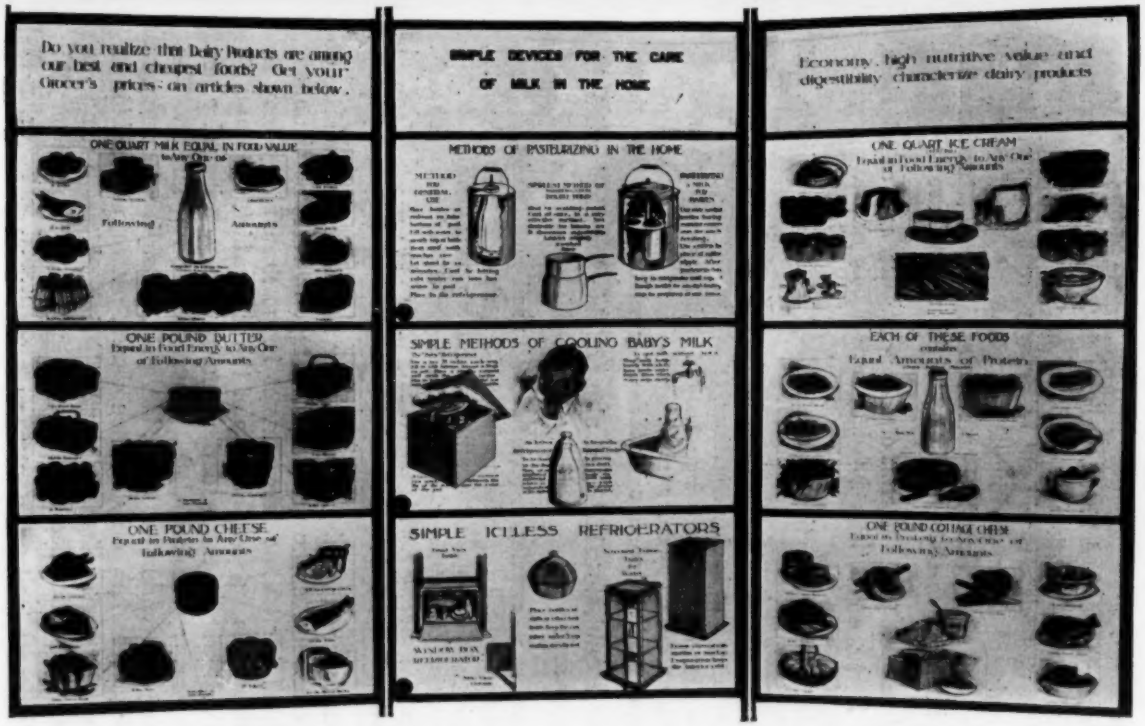
Do you realize that Dairy Products are among our best and cheapest foods? Get your Grocer's prices on articles shown below.
ONE QUART MILK EQUAL IN FOOD VALUE
ONE POUND BUTTER
ONE POUND CHEESE
SIMPLE DEVICES FOR THE CARE OF MILK IN THE HOME
METHODS OF PASTEURIZING IN THE HOME
SIMPLE METHODS OF COOLING BABY'S MILK
SIMPLE ICELESS REFRIGERATORS
Economy, high nutritive value and digestibility characterize dairy products
ONE QUART ICE CREAM
EACH OF THESE FOODS
ONE POUND COTTAGE CHEESE

FIG. 5. AN EXHIBIT ILLUSTRATING THE FOOD VALUE AND CARE OF MILK

The charts were made entirely by hand, most of the illustrations being in color. The reading matter has been reduced to a minimum, the story being told principally by pictures.

department. The standard sized wings which the frames carry are especially suited to this purpose since each chart may show one phase of the extension work for one year. By keeping the exhibit up-to-date it will not be many years before an interesting series of charts showing the development of each phase will have been accumulated. Some of the phases of extension work which lend themselves to display in this manner are:

Visits made in the interest of certain projects, such as calf clubs, cow testing associations, breeders associations, creamery improvement, etc.

Location of coöperative cow testing and breeders association, bull associations, etc.

Location of farms coöperating with the department in cost accounting, milking machine investigations, etc.

Location of breeders doing advanced register testing.

Routes covered by dairy trains.

Location of communities in which dairy exhibits have been shown.

Other subjects which are also suitable for display in this manner are:

Location of creameries, cheese factories and condensaries.

Districts supplying milk to large cities, showing railroad routes, shipping stations, amount of milk shipped from each locality, etc.

Location of breeders of pure bred dairy cattle of different breeds.

Number of dairy cows in each county related to value of land, kind of soil and crops, etc.

Outline maps of the state showing names and boundaries of the counties may be used to advantage in charting the above subjects. If outline maps cannot be purchased they may be made as follows; secure a map of the state which is of suitable size and trace the boundaries, county names, principal rivers and cities on tracing cloth. From the tracing make a Van Dyke print. From the latter, blue prints or sepia prints may be made which show only the boundaries, names, etc. in blue or brown, the remainder of the print being white. Placing the map upon a suitable foundation, the points of interest may be indicated by cloth covered tacks, glass headed tacks, or small

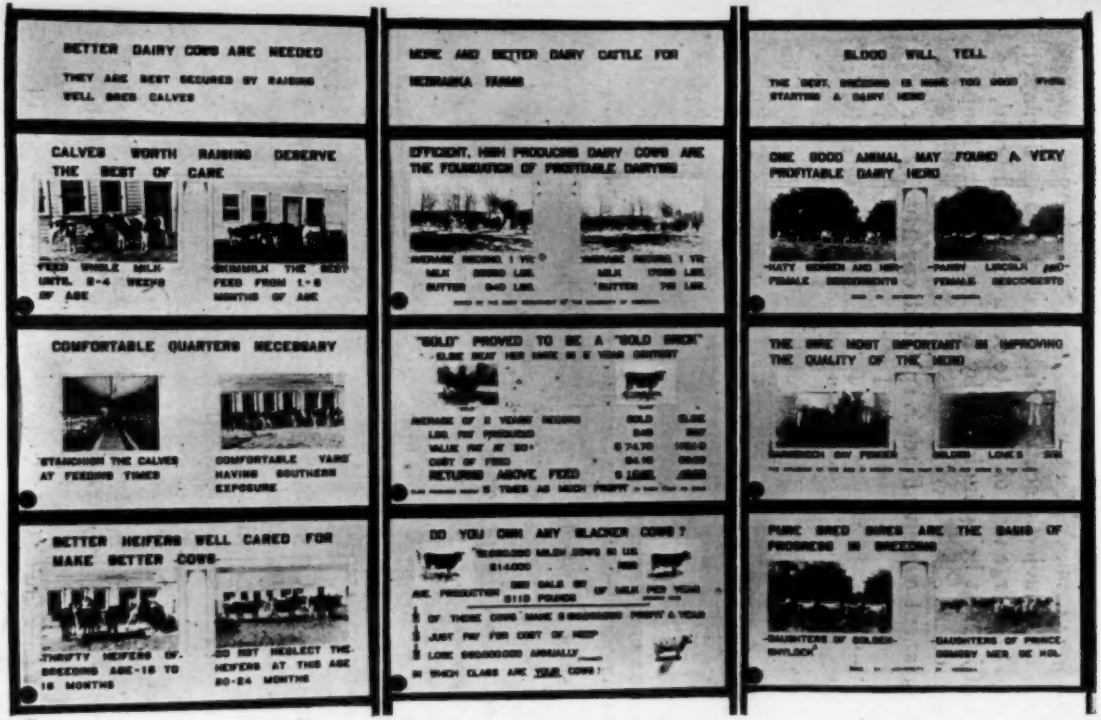
BETTER DAIRY COWS ARE NEEDED
THEY ARE BEST SECURED BY RAISING WELL BRED CALVES
MORE AND BETTER DAIRY CATTLE FOR NEBRASKA FARMS
BLOOD WILL TELL
CALVES WORTH RAISING DESERVE THE BEST OF CARE
FEED WHOLE MILK UNTIL 3-4 WEEKS OF AGE
SKIMMILK THE BEST FEED FROM 1-6 MONTHS OF AGE
EFFICIENT, HIGH PRODUCING DAIRY COWS ARE THE FOUNDATION OF PROFITABLE DAIRYING
ONE GOOD ANIMAL MAY FOUND A VERY PROFITABLE DAIRY HERD
COMFORTABLE QUARTERS NECESSARY
STANCHION THE CALVES AT FEEDING TIMES
COMFORTABLE YARD HAVING SOUTHERN EXPOSURE
"GOLD" PROVED TO BE A "GOLD BRICK"
THE SIRE MOST IMPORTANT IN IMPROVING THE QUALITY OF THE HERD
BETTER HEIFERS WELL CARED FOR MAKE BETTER COWS
THRIFTY HEIFERS OF BREEDING AGE-15 TO 18 MONTHS
DO NOT NEGLECT THE HEIFERS AT THIS AGE 20-24 MONTHS
DO YOU OWN ANY SLACKER COWS?
PURE BRED SIRES ARE THE BASIS OF PROGRESS IN BREEDING

FIG. 6. SPECIMENS OF CHARTS

Gummed letters and enlarged photographs were employed in preparing these charts. The decorative borders around the photos were made by hand with drawing ink.

celluloid flags of different colors. The positions of these may be changed or others added at will.

Some of the subjects mentioned above may also be displayed by means of a large map of the state outlined on wall board, the points of interest being indicated by miniature electric lamps of different colors.

A permanent exhibit affords a splendid opportunity for presenting the results of experimental work, since those who visit the institution are naturally more interested in its activities than the average sightseer at a fair. By this means it is possible to show what the department has done, is doing and is competent to do for the state. Expansion needs in men, buildings, and equipment may also be presented in this way.

Among the articles of interest which are suitable for display in a permanent exhibit are the following: Art models of butter, cheese, milk, condensed milk, ice cream, both plain and fancy, and other articles of food; butter cartons; milk bottles; milk bottle caps; cream whippers; home pasteurizers; thermopak carriers for ice cream; barn, milk house and creamery models; parcel post wrappers for butter and cheese; iceless refrigerators; Babcock test glassware; fancy cutouts and other devices for advertising dairy products; products made from milk and commercial articles in which casein is used in their manufacture.

A milk production exhibit room may be equipped so that it will be of interest not only to visitors but may be used in instructional work also. Since much of this material is of a different nature than that mentioned heretofore, such an exhibit should be a distinct unit. Many manufacturers are willing to loan suitable equipment such as cow stalls, water bowls, floor materials, milking machines, feed trucks, litter carriers, cream separators, cooling tanks, etc. Some other items of interest to be included are: A complete set of record sheets for milk and other herd records, blue prints for barn and milk house construction, silo models, bull staffs, clipping machines, common veterinary instruments, ear tags, and other marking devices, covered milk pails, strainers, milk coolers, etc.

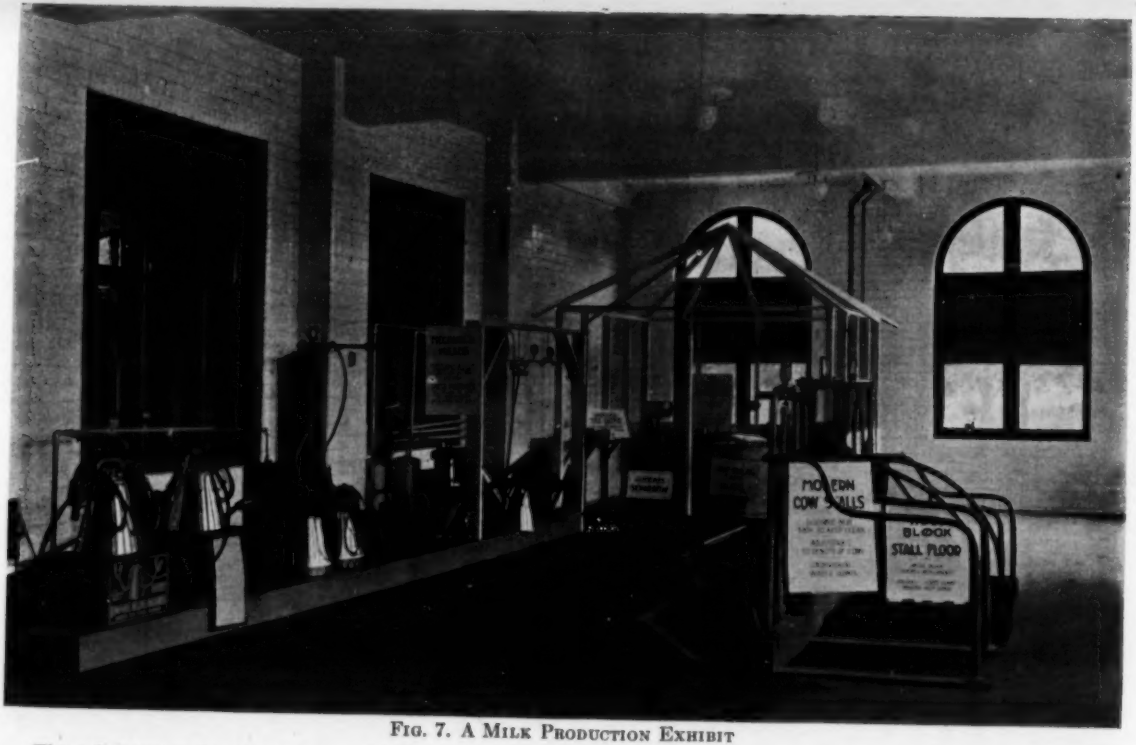


FIG. 7. A MILK PRODUCTION EXHIBIT

Three different makes of milking machines can be operated for demonstration. The skeleton building in the background illustrates a desirable type of construction and arrangement of equipment for a farm milk house. Modern stall equipment and different kinds of flooring materials are shown at the right.

### CHARTS SHOULD BE PROTECTED

Well made charts are too expensive to be exposed to flies, dust and the handling of visitors as they soon become so soiled that one of the valuable qualities of a good exhibit—attractiveness—is soon lost. There are several ways of protecting charts, perhaps the most common being the use of glass. Exhibits and charts covered by a good grade of glass have a finished and neat appearance as well as being quite well protected. Of course, glass is not desirable for a traveling exhibit on account of breakage and weight. Transparent celluloid sheeting in sizes up to 20 by 30 inches forms a good substitute for glass in covering charts, as it obviates the objections mentioned. All the charts illustrated in figures 3, 5 and 6, are covered with this material. Another method of preserving charts is to paint the material on which the charts are to be made with two coats of oil paint and use oil paint in lettering the charts. Such charts can then be washed. The charts shown in figure 1 were made in this manner, the material used for the foundation being beaver board.

## NOTES AND REFERENCES

The following books may be found useful in obtaining ideas relative to the preparation of exhibits.

*Graphic Methods for Presenting Facts*, by W. C. Brinton. The Engineering Magazine Company, New York.

*Psychology of Advertising*, by W. C. Scott. Small, Maynard & Company, Boston.

*A. B. C. of Exhibit Planning*, by D. G. and Mary B. Routzahn. The Russell Sage Foundation, New York.

## PARTIAL LIST OF MANUFACTURERS OF EXHIBIT MATERIAL

### DISPLAY FIXTURES

Multiplex Display Fixture Company, St. Louis, Mo.
Library Bureau, Chicago, Ill.
Educational Exhibition Company, Providence, R. I.
Universal Fixture Corporation, 133–135–137 West 23rd Street, New York, N. Y.

### MAP TACKS AND PINS, ETC.

Moore Push Pin Company, Philadelphia, Pa.
Educational Exhibition Company, Providence, R. I.

GUMMED LETTERS AND LABELS

The Tablet and Ticket Company, Chicago, Ill.

TRANSPARENT SHEETING

The Arlington Company, New York City.

ICE CREAM AND OTHER FOOD MODELS

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# OPEN FORUM

## Dairy Cattle Score Cards

The dairy cow is coming to her own. The demand for dairy cattle is now far in excess of the supply and there is every indication that this condition will continue. The dairy cattle courses have been popular, in the past, with a considerable number of the students of our schools and colleges. As the interest in dairying increases it is reasonable to believe that a larger number of students will be interested in the study of dairy cattle. It should also be remembered that the Smith-Hughes Act will make it possible for thousands of students to study Agriculture in the high schools.

The official score cards of the different breed associations are not a credit to the breed of cows which they represent and they are not suitable for student use. Some of the cards are too indefinite, while others entirely omit several of the things that are universally required of a dairy cow. None of the cards have an up-to-date arrangement.

The old type of score card has been discarded by practically all of the leading dairy instructors because it was too long, did not sufficiently emphasize essential points, paid too much attention to fancy points and failed to lay sufficient stress on the relation between form and function.

The average breeder of cattle usually gets his ideas of breed type from actual observation and from what he learns from other men at sales and show rings, rather than from the use of the score card. If a beginner does study the card for his breed, he is apt to discover that the most progressive breeders do not pay much attention to some of the things emphasized by the card and insist on other characteristics probably not mentioned on the card. For example: Nearly all of the cards give considerable space and credit to the escutcheon and practically ignore the alert, energetic appearance of the animal, while in the sale stable or show ring few even look for the escutcheon and if an animal is not alert it is not even considered. After all, the chief function of a score card is to indicate to the breeder or student what characteristics of form indicate dairy temperament, capacity for feed, well developed milk secreting organs, etc. The old style card did not even attempt to do this.

It is quite essential for the breed card to state the required size and color of the animals of that breed. Some of the breed score cards are lacking in this respect. It is not uncommon to find those who should know better insisting that a white marking on a Jersey is not allowed, while all sorts of notions exist as to the color markings allowed on a Holstein.

If the instructor knows the breed, the present cards serve their purpose quite well but now when Agriculture is being taught in all kinds of schools the instructor may need a good guide more than the students.

One reason why the score cards for the dairy cattle breeds have not been revised is that the members of the breed associations have not realized the need of a change and have not taken the time or interest to consider the matter. Another reason is that the dairy instructors who use the cards, instead of bringing the matter to the attention of the breed associations have relied on the improved dairy cow card and supplied the necessary information about breed characteristics and type.

There appears to be an evident need for revised score cards for the several breeds of dairy cattle. Would it not be well for the American Dairy Science Association to take this matter up and urge the breed association to provide revised cards in order that the students and breeders may have an adequate guide for the study of the several breeds of dairy cattle.

J. R. Dice,
*Morrisville, N. Y.*

# COMMITTEE APPOINTMENTS FOR THE AMERICAN DAIRY SCIENCE ASSOCIATION

*Dairy Farm Score Card*

ERNEST KELLY, *Chairman*
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W. A. STOCKING
I. C. WELD
H. A. HARDING

*Milk Quality*

H. A. HARDING, *Chairman*
W. A. STOCKING
R. S. BREED
E. G. HASTINGS
J. D. BREW

*Bacteriological Methods for Market Milk*

R. S. BREED, *Chairman*
L. A. ROGERS
E. G. HASTINGS
G. C. SUPPLEE
B. W. HAMMER

*Relation to Breed Associations*

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H. H. WING
ROY T. HARRIS
E. G. WOODWARD
W. W. YAPP
H. W. NORTON, JR.
H. H. KILDEE

*Methods Conducting Student Dairy Cattle Judging Contest*

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WILLIAM REGAN
E. L. ANTHONY
H H. KILDEE
J. B. FITCH
W. W. SWEET

*Official Methods for Testing Milk and Cream for Butter Fat*

O. F. HUNZIKER, *Chairman*
F. W. BOUSKA
FRED RASMUSSEN
H. C. TROY
L. A. ROGERS

*Legal Standards for Butter*

M. MORTENSEN, *Chairman*
S. C. THOMPSON
E. S. GUTHRIE
G. H. BENKENDORF
F. W. BOUSKA

*Revision of Constitution and By-Laws*

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O. F. HUNZIKER
M. MORTENSEN
W. J. FRASER
R. A. PEARSON
J. H. FRANDSEN

*Statistics on Production and Marketing of Dairy Products*

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*Graduate Instruction in Dairying*

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C. W. LARSON

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H. E. VAN NORMAN — J. A. GAMBLE
ERNEST KELLY

*Feeding Standards for Milk Production*

C. LARSEN, *Chairman* — A. A. BORLAND
C. H. ECKLES — E. S. SAVAGE
HELMER RABILD — C. C. HAYDEN

*Score Cards for Dairy Products*

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M. MORTENSEN — W. W. FISK
S. C. THOMPSON — J. L. SAMMIS

*Methods for Conducting Student Dairy Products Judging Contest*

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C. E. LEE — N. W. HEPBURN
W. W. FISK

*Cream Grading*

J. H. FRANDSEN, *Chairman* — G. S. HINE
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C. F. HUNZIKER — W. W. FISK
H. A. RUEHE

*Official Methods for Testing Butter for Butter Fat*

H. C. TROY, *Chairman* C. E. GRAY
N. W. HEPBURN

*Statistics of Milk and Cream Regulations**
*Cost of Production*

OSCAR ERF, *Chairman* G. F. WARREN
F. A. PEARSON A. C. ANDERSON
ERNEST KELLY

* At the request of Chairman Weld this Committee will be discontinued.